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CONTRIBUTIONS TO CANADIAN PALEONTOLOGY

(five papers)

William B.N. Berry and B.S. Norford;
R.E. Smith; D.E. Jackson, J. Wm. Kerr
and D.W. Morrow; T.P. Poulton;
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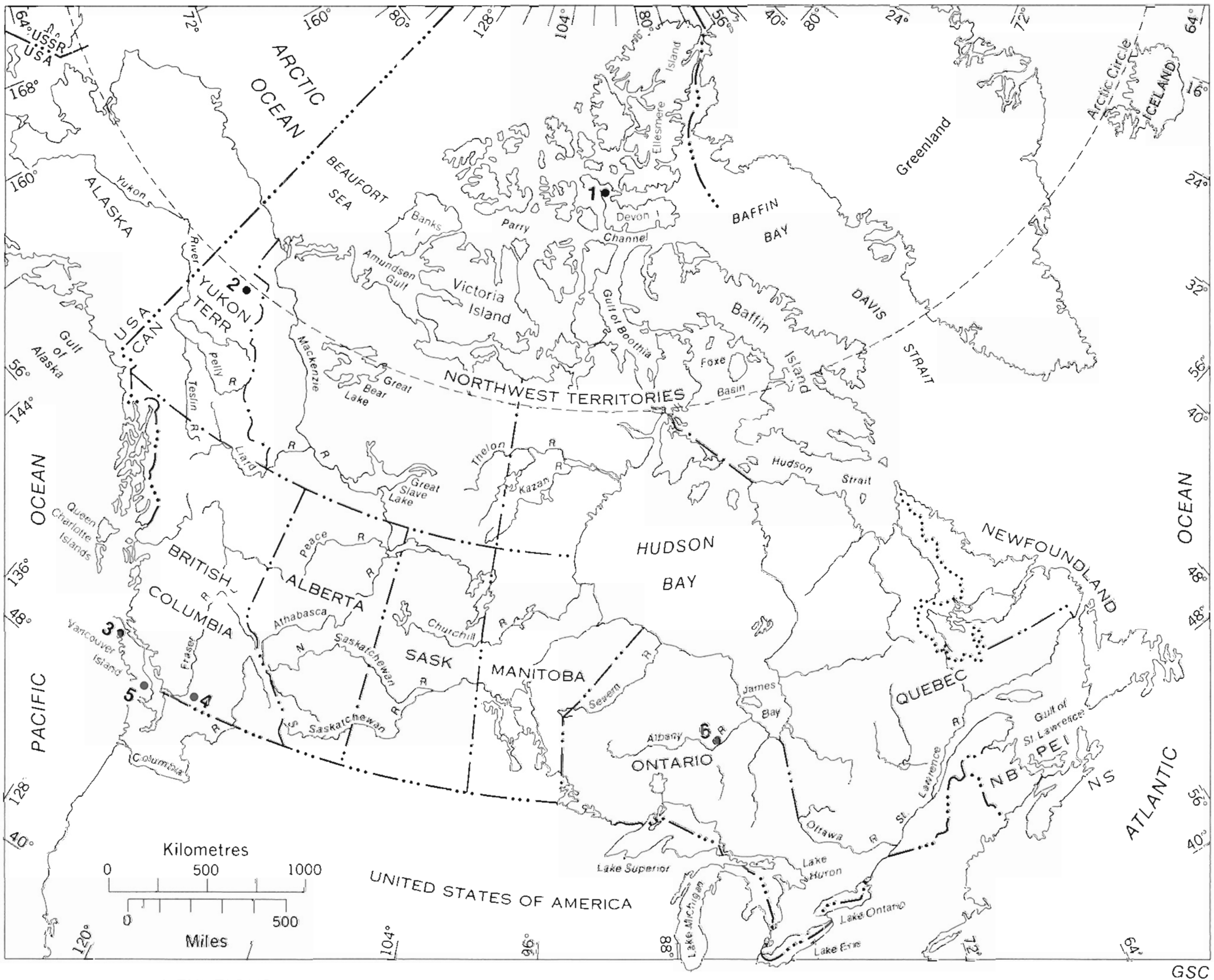
PREFACE

From time to time it is appropriate to issue several short papers on paleontological topics as a single bulletin under the general title of *Contributions to Canadian Paleontology*. This Bulletin contains five papers describing a number of different groups of fossils. Such detailed studies provide the foundations essential to refinement and application of schemes of biostratigraphic zonation that are fundamental to accurate stratigraphic interpretation of the sedimentary basins of Canada.

D. J. McLAREN,
Director-General,
Geological Survey of Canada

OTTAWA, July 10, 1975



GSC

TEXTFIGURE 1. Locality map for all papers.

1. Douro Range, Devon Island (Smith; Jackson, Kerr, and Morrow).
2. Trail River, Richardson Mountains, Yukon Territory (Berry and Norford).
3. Western Vancouver Island, British Columbia (Poulton).
4. Manning Provincial Park, British Columbia (Poulton).
5. Cowichan Lake, southern Vancouver Island, British Columbia (Poulton).
6. Mattagami Formation, Moose River Basin, Ontario (Hopkins and Sweet).

EARLY LATE CAMBRIAN DENDROID GRAPTOLITES FROM THE NORTHERN YUKON

by William B.N. Berry[1] and B.S. Norford

Abstract

A diverse fauna of poorly preserved graptolites is described from the lower part of the Road River Formation. The graptolites occur in a stratigraphic interval that is at least 1,100 feet (335 m) thick and includes two beds containing trilobites that indicate early Dresbachian age (late *Cedaria* Zone or *Crepicephalus* Zone). The graptolites seem to be among the oldest dendrograptid graptolites yet recorded and include species of *Callograptus*, *Dendrograptus*, *Desmograptus*, and *Dictyonema*.

Résumé

Une fauna variée mais mal préservée de graptolites a été découverte dans la partie inférieure de la formation Road River. Les graptolites se trouvent dans une série stratigraphique d'au moins 1,100 pieds (335 m) d'épaisseur, qui comprend deux bancs à trilobites. Ces trilobites indiquent un âge Dresbachien inférieur (fin de la zone a *Cedaria*, ou de la zone a *Crepicephalus*). Les graptolites semblent être parmi les plus anciens specimens du type dendrograptide découverts à ce jour et sont répresentés par les espèces des genres *Callograptus*, *Dendrograptus*, *Desmograptus* et *Dictyonema*.

Previously Described Cambrian Graptolites

The only previously recorded Cambrian graptolites are Late Cambrian forms from North America described by Ruedemann (1933, 1947) and Decker (1945); Middle Cambrian material from Norway described by Öpik (1933), from the Cantabrian Mountains, Spain by Sdzuy (1974), and from Siberia by Obut (1964, 1974); and Middle and Late Cambrian specimens from the Huskisson River area of Tasmania described by Quilty (1971). Bulman (1970) discussed the Cambrian graptolites (except those later described from Spain and Tasmania) and pointed out that the Siberian Middle Cambrian graptolites are "of uncertain taxonomic position (possibly representing a new order, but possibly dendroid or tuboid)" and that the single Norwegian Middle Cambrian specimen has been "attributed to *Dendrograptus*." As Öpik (1933, p. 115) noted, the affinities of the Norwegian specimen are dubious. The Spanish specimens are similar to those from Siberia (Sdzuy, 1974). Quilty (1971) described three poorly preserved specimens that he thought could be attributed to *Dendrograptus* and cited the presence (ibid., p. 174) of *Protospongia*, "hydroids and the brachiopods *Protorthis* and ?*Otusia*" in association with the possible dendroids, and stated that Öpik (1951) had studied the fauna and regarded it as "probably Middle Cambrian" in age. The precise phyletic relationships and the age of these Tasmanian specimens of *Dendrograptus* appear to be uncertain. Quilty (1971) also recorded specimens of *Mastigograptus*, *Cactograptus*, and *Acanthograptus* from Middle Cambrian rocks in Tasmania. Bulman (1970) indicated that the taxonomic positions of *Cactograptus* and *Mastigograptus* are uncertain, but he included members of the Family Acanthograptidae in the Order Dendroidea and the Tasmanian acanthograptids appear to be the oldest demonstrably dendroid graptolites described to date.

The oldest previously recorded clearly dendrograptid dendroids are in Late Cambrian faunas described by Ruedemann (1933, 1947) and Decker (1945). Most of the described specimens are from the later part of the Late Cambrian (Franconian and Trempeleauian). Some specimens from the Nolichucky Shale in Tennessee may be as old as early Dresbachian (Christina Lochman-Balk, written com., 1974).

Stratigraphic Occurrence

Cambrian stratigraphy of the northern Yukon recently has been outlined by Fritz (1974), following earlier studies by Proctor and Norford (*in* Norris, Price, and Mountjoy, 1963; and *in* Norford, 1964) as part of Operation Porcupine of the Geological Survey of Canada. Fritz's Section 4 (Road River) lies about 13 miles (21 km) northwest of Trail River and shows that Middle Cambrian fine-grained sandstone is overlain by limestone and shale of the Road River Formation that bear long-ranging *Protospongia* sp. close to the base and Late Cambrian (*Cedaria–Crepicephalus* Zones) faunas several hundred feet higher. At Trail River, the contact appears to be gradational (Norford, 1964, p. 3) but diagnostic fossils are rare in the underlying sandstone; those that have been found at Wind River [about 100 miles (160 km)

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south of Trail River] indicate the *Albertella* and *Glossopleura* Zones (Fritz, 1974) but later time may be represented within the rock-unit.

Cambrian graptolites and trilobites were collected by Norford and Upitis in 1962 from stratigraphic sections in the Road River Formation of the Richardson Mountains (most collections are from the Trail River Section, Textfig. 1, loc. 2, lat. 66°25′N, long. 135°32′W; Norford, 1964, p. 91, 92, 133, 134). The stratigraphic positions in the section are listed below. The graptolites have been identified by the senior author and the trilobites by W.H. Fritz.

GSC loc.	Feet (m) above base of measured section	Taxa
53165	1,087 (331)	*Cedaria* cf. *C. prolifica* Walcott *Crepicephalus* sp. *Kingstonia* sp. *Lonchocephalus ?* sp. *Shickshockia ?* sp. *Tricrepicephalus* sp.
53164	1,066 (325)	*Callograptus* sp. 1 *Dictyonema* sp. 1 *Dendrograptus ?* sp.
53163	870 (265)	*Callograptus* sp. 2 *Dictyonema* sp. 2 *Dendrograptus* sp. 1 *Dendrograptus* sp. 2
53162	803–805 (244–245)	*Tricrepicephalus ?* sp.
53161	785 (229)	*Dendrograptus* sp. 1?
53160	256–258 (78–79)	*Dictyonema* sp. 1 *Dendrograptus* sp. 3 *Dendrograptus* sp. 4 *Dendrograptus ?* sp. *Dictyonema ?* sp.
53159	189 (58)	*Dendrograptus* sp. 1? *Dendrograptus* sp. 5 *Dendrograptus* sp. 6 *Dendrograptus* spp.? (several rhabdosomal fragments)

Fritz considers that both collections of trilobites (GSC locs. 53162 and 53165) may belong to the upper part of the *Cedaria* Zone but more probably indicate the *Crepicephalus* Zone. Both zones are lower Dresbachian and thus the ages of the underlying and interbedded graptolites are early Dresbachian and some perhaps somewhat older. Both collections are from beds of biogenic limestone; thus the specimens were transported before burial and could be slightly older than the containing beds.

Norford also obtained graptolites from the lower part of the Road River Formation in two small collections in the same area as the Trail River section. GSC locality 53166 is from 24.5 feet (7.4 m) above the base of the Road River Formation at another locality (lat. 66°25′N, long. 135°32′W) on the Trail River; small fragments of *Desmograptus* sp. are present. GSC locality 53168 is from a two-foot (0.6 m) interval 300 feet (90 m) stratigraphically above the base of the Road River Formation exposed in a Trail River tributary section (lat. 66°28′N, long. 135°36′W; Norford, 1964, p. 139), and includes *Desmograptus* sp. and *Dendrograptus ?* sp. The precise ages of these two collections are not known, but their stratigraphic positions toward the base of the Road River Formation indicate that both probably are of Late Cambrian age and within or below the *Crepicephalus* or *Cedaria* Zone. The specimens of *Desmograptus* seem to be the oldest known representatives of the genus. Previously, Bulman (1970) noted that, to that date, the oldest recorded desmograptids were Early Ordovician, and Quilty (1971) suggested that a specimen of *Desmograptus* from the Zeehan District in Tasmania was Early Ordovician.

The Faunas

The Yukon Late Cambrian graptolites are poorly preserved, as are most other recorded Cambrian graptolites. Among the Yukon specimens, only the basic outlines of the rhabdosome branching may be determined. Thecae are preserved so infrequently that their characteristics cannot be used in comparisons with previously described specimens. Because thecae are so rare in the Yukon specimens, and because Ruedemann (1933, 1947) and Decker (1945) commonly described thecal characteristics in other North American Late Cambrian and younger dendroid graptolites, precise comparison with these other North American faunas is not possible. Decker (1945) described an apparently especially abundant dendroid fauna from Franconian age beds in the Wilberns Formation in Texas, but the specimens he illustrated are so fragmentary that comparisons with them are not possible.

Dendroid Relationships

The presence of four different dendrograptid genera (*Callograptus*, *Dendrograptus*, *Desmograptus*, and *Dictyonema*) in the Yukon collections indicates that a significant degree of phyletic differentiation had taken place among the dendroid graptolites by the early part of the Late Cambrian. Four main phyletic lineages (the families of dendroid graptolites) may be recognized among the graptolites assigned to the Order Dendroidea by Bulman (1970). Of the four, the Anisograptidae and Ptilograptidae appear in the Tremadoc–Arenig (latest Cambrian – Early Ordovician) interval. The oldest members of the Dendrograptidae appear to be the Yukon specimens, perhaps together with those from the Nolichucky Shale in Tennessee. The earlier known Acanthograptidae are those described by Quilty (1971) from Tasmania.

Of the four dendroid families, the members of the Family Acanthograptidae differ from the other three more than the other three do among themselves. The Acanthograptidae are characterized by irregularly branching stipes and by their very slender, elongate tubular thecae. Most of them have a shrub-like aspect. Certain of them (*Koremagraptus*, for example) appear to be remarkably similar to certain tuboid graptolites such as *Reticulograptus*. Indeed, the acanthograptids may include those graptolites that phyletically link the graptolites that had shrub-like, seaweed-like aspects and modes of life with those that were primarily encrusting in mode of life (tuboids, crustoids, camaroids, and stolonoids). Modifications of the rhabdosome more suited to a fan-like or shrub-like growth habit could have resulted in development of the graptolites included in the Dendrograptidae. The now known fossil record suggests that these developments were taking place during the Middle Cambrian, and that several stocks of dendrograptids were established by the early Late Cambrian. The Yukon dendroids, though imperfectly preserved, broaden understanding of the evolutionary development of the oldest graptolites.

Acknowledgments

O.M.B. Bulman verified some preliminary determinations of the graptolites made by Norford. W.H. Fritz kindly studied the trilobites, and he and R. Thorsteinsson criticized the manuscript of this publication.

Systematic Paleontology

This section is authored by Berry. Prefix GSC refers to specimens in the type collection of the Geological Survey of Canada, Ottawa. The taxonomic categories, their diagnoses, and the morphological terms used follow Bulman's (1970) synthesis.

Class **GRAPTOLITHINA** Bronn 1846

Order DENDROIDEA Nicholson 1872

Family DENDROGRAPTIDAE Roemer *in* Frech 1897

Genus ***Dendrograptus*** Hall 1858

Dendrograptus sp. 1

Plate 4, figure 1

Material. One large but incomplete rhabdosome (GSC 40940) and four or five poorly preserved rhabdosome fragments from GSC locality 53163, and possibly fragmentary specimens from localities 53159 and 53161.

Description. The figured specimen is broad, has a shrub-like appearance and is approximately 55 mm wide and 45 mm long. The stipes commonly branch dichotomously, but some were produced by lateral branching. Branching occurs at irregularly spaced intervals of about 4 to 6 mm in the proximal part of the rhabdosome and at intervals of about 1 to 3.5 mm in the distal part. Stipes produced by dichotomous branching commonly diverge from each other at 15 to 30 degrees. Those diverging from each other at the wider angles are more common in the proximal part, whereas those diverging from each other at narrower angles are more common in the distal part. Stipes that were produced by lateral branching are more common in the proximal part of the rhabdosome than in the distal. Those developed by lateral branching diverge from a principal stipe at 40 to 55 degrees.

Stipes are mostly about 0.3 mm wide but some are up to 0.5 mm wide. They are essentially straight for the greater part of their length.

Thecae are difficult to distinguish. Apparent autothecae are spaced at about 4 to 5 in 5 mm, and the few that can be seen are inclined to their stipe axis at 18 to 25 degrees. Their apertural margins are straight, armed with a moderate denticle, and are normal to their stipe axis. Autothecal overlap is about one-third.

Discussion. The general aspect of branching suggests that the species had a shrub-like aspect in life. The colony branched relatively little initially, but as it developed branching became more frequent. The breadth of the specimen and the thinness of the stipes (most of them are about 0.3 mm wide) are characteristics of the species that set it apart from others.

Dendrograptus sp. 2

Plate 3, figure 3

Material. Two fragmentary specimens from GSC locality 53163.

Description. The larger fragment (GSC 40941) is about 3 mm long. A central, rather wide stipe appears to give rise to two stipes by dichotomy. Lateral branching takes place in each of these stipes and dichotomy in the remainder of the rhabdosome. The stipes between points of branching seem to alternate between being relatively short (1 to 4 mm) and relatively long (4 to 8.5 mm). They diverge from each other at 50 to 63 degrees at dichotomy, but commonly curve toward each other within approximately 1 mm to enclose angles of about 10 to 20 degrees.

The initial stipe is 0.7 to 0.8 mm wide. The stipes produced at each dichotomy are slightly narrower than those from which they originate. The most distal ones are 0.3 to 0.4 mm wide.

Discussion. These rhabdosome fragments are characterized by the slight narrowing in stipe width after each dichotomy and by their general branching patterns in which shorter stipes alternate with longer ones between dichotomies. The basic aspect of the rhabdosome fragments suggests that the whole colony may have had a bush-like or shrub-like appearance in life, and that it may have developed from a stout central stem.

Dendrograptus sp. 3

Plate 3, figure 2

Material. One immature rhabdosome (40942) and two or possibly three rhabdosome fragments from GSC locality 53160.

Description. The figured rhabdosome is approximately 18.5 mm long and 15.3 mm wide at maximum width. At its apical end, it has a small disc-like structure that is 0.7 mm long and 0.3 mm wide and joined to a single stem-like stipe that is 0.9 mm long and widens from 0.3 mm at the join to 0.6 mm at the point of branching.

Two primary stipes developed, apparently by dichotomy, from the central stem-like stipe. The primary stipes are 2.5 mm and approximately 4.5 mm long before they branch dichotomously, producing stipes that are 1.0 to 1.7 mm long before they too branch dichotomously. The next stipes are about 3 to 8 mm long before they branch by dichotomy.

In general, the stipes produced at each dichotomy diverge from each other at 70 to 85 degrees for 1.3 to 1.6 mm, then turn inward toward each other through an angle of 45 to 55 degrees to become subparallel. The stipes are 0.45 to 0.55 mm wide throughout the rhabdosome.

Thecae were not observed, but the stipes have a generally "wavy" or "zig-zag" aspect which appears to result from one (or perhaps more) theca being formed at an angle to the general trend of the stipe axis. Successive thecae seem to be produced at a slight angle to the stipe axis, alternately to its left and right.

Discussion. These specimens differ from other dendrograptids in the Yukon collections by the lengths of the stipes between dichotomies in the proximal part of the rhabdosome (which are somewhat longer than those in the other species of *Dendrograptus*) and by the marked divergence of the stipes at each dichotomy followed by incurving to become essentially subparallel.

Dendrograptus sp. 4
Plate 4, figure 2

Material. One fragmentary specimen (GSC 40943) from GSC locality 53160.

Description. The rhabdosome fragment is approximately 15 mm long and 12 mm wide and apparently developed from a thecate stipe. Two parts of the specimen may be recognized and differ in branching characteristics. One part (central and right side of fig. 2) branches dichotomously three times. The points of dichotomy are spaced at intervals of 1.5 to 2 mm. The other part (left side) branches less frequently. The initial stipe dichotomy is about 6 mm from the thecate stipe. Subsequent dichotomies occur at 2 to 4 mm intervals. The stipes arising from dichotomy diverge from each other initially at 70 to 80 degrees, after a distance of about 1 to 2 mm they turn toward each other through an angle of 38 to 45 degrees (commonly about 40 degrees) to become essentially subparallel.

The stipes in the main part of the rhabdosome are 0.6 to 0.75 mm wide. The thecate stipe is 1.0 mm wide.

Thecae are indistinct, but those in the main part of the rhabdosome appear to be spaced at 6 to 7 in 5 mm. Thecae on the initial thecate stipe are spaced at 4 in 5 mm. Their apertural margins are moderately denticulate and are normal to the stipe axis.

Discussion. The greater stipe width in this specimen sets it apart from other species of *Dendrograptus* in the Yukon collections. Another characteristic feature of the specimen is the pattern of stipe curvature, that is diverging markedly after stipe dichotomy but with subsequent inward curvature to a nearly subparallel orientation.

Dendrograptus sp. 5
Plate 3, figure 1

Material. One possibly immature rhabdosome (GSC 40944) from GSC loc. 53159.

Description. The specimen has a generally shrub-like aspect, is approximately 14 mm long and is 18.5 mm wide at maximum width.

The rhabdosome appears to have originated from a single stipe or "stem" that is 1.3 mm long and 0.5 mm wide close to the point from which primary stipes develop. The two centrally positioned primary stipes branch dichotomously at approximately 2 mm from their origin, and the stipes produced at that dichotomy themselves branch dichotomously at 2.5 to 3 mm from their origin. At the second dichotomy, two of the stipes produced branch by dichotomy at a distance of 2.5 to 3 mm from their point of origin while the other stipes remain unbranched. The outer two primary stipes branch by dichotomy at distances of 2.4 and 5.5 mm from their origin. Of the stipes formed at that initial set of dichotomies, one does not branch again, but the others branch at distances of 1 to 3.5 mm from their origins.

The stipes initially diverge from each other at dichotomy at 55 to 75 degrees but they turn toward each other within 1 to 1.5 mm to ultimately enclose an angle of 5 to 15 degrees. They are 0.4 to 0.55 mm wide throughout the rhabdosome.

Thecae are indistinct except on two stipes. There, the apparent autothecae are spaced at 8 to 9 in 5 mm, and they have markedly curved free ventral walls. Their apertural margins are straight and normal to the stipe axis. The apertures have small denticles.

Discussion. Whether or not the specimen described is an immature rhabdosome or but a rhabdosome fragment is uncertain. The fairly constant stipe width of 0.5 mm and the frequent stipe dichotomies, commonly at intervals of 2 to 3 mm in the proximal part of the rhabdosome, differentiate this species from other species of *Dendrograptus* from the Yukon.

Dendrograptus sp. 6
Plate 5, figures 1, 2

Material. Fragments (including GSC 42537 and 42538) from two or possibly three specimens from GSC locality 53159.

Description. The largest fragment (GSC 42538) is about 72 mm long and 40 mm wide. It has a central stem-like stipe from which other stipes originate. The stipes are 0.8 to 1.1 mm wide in the proximal parts of the specimens at hand, and 0.5 to 0.7 mm wide in the distal parts. Most are essentially straight or slightly flexed.

Branching patterns are uncertain because the available fragments seem to be from distal parts of rhabdosomes. Branching is rather infrequent, but where present is dichotomous throughout most of the specimens, although some lateral branches occur in the apparently medial part of one specimen. These form a 40 to 45 degree angle with the stipe from which they originate. Stipes that arise by dichotomy enclose a 20 to 35 degree angle. The angle between two stipes that originate by dichotomy is about 30 to 35 degrees in the medial part of the rhabdosome and about 20 degrees in the more distal parts. Most stipes branch once and then remain unbranched for the remainder of their extent in the available specimens. Unbranched stipes as much as 45 mm long occur in one specimen.

Thecae (presumably autothecae) are visible on many stipes, spaced at 7 to 8 in 10 mm. They overlap about one-half and are inclined to their stipe axes at angles of 12 to 22 degrees. Thecal apertures bear a distinct flange, or perhaps lip, on their ventral margins.

Discussion. The infrequent branching and the relatively wide stipes set these rhabdosome fragments apart from other *Dendrograptus* in the collections. Because only rhabdosome fragments are present, the generic assignment may be questioned, but the general branching aspect appears most similar to that among members of the genus *Dendrograptus*.

Genus ***Callograptus*** Hall 1865

Callograptus sp. 1
Plate 1, figure 2

Material. One almost complete rhabdosome (GSC 40937) from GSC locality 53164.

Description. The specimen is preserved as approximately semicircular, but the orientation of the stipes suggests that it was conical when in life position. The proximal end is not preserved. The maximum length of the specimen is about 28 mm.

The stipes are spaced at 7 to 8 in 5 mm, are 0.4 to 0.5 mm wide, and are separated by narrow interspaces that are 0.15 to 0.25 mm wide. The stipes branch by bifurcation and turn fairly sharply after bifurcation to become subparallel. They are essentially straight. Stipe bifurcation occurs irregularly at intervals of 5 to 12 mm, mostly within 7 to 10 mm of the previous bifurcation. A few stipes appear to bifurcate only once in the length of the rhabdosome.

Thecae were not observed. Slender (0.1 to 0.2 mm wide) dissepiments between some adjacent stipes in the distal part of the rhabodsome seem to have formed by a group of thecae diverging from one stipe and merging with those of an adjacent stipe. Dissepiments are rare and occur only once between the same pair of stipes.

Discussion. The relatively narrow interspaces between the stipes and the greater width of the stipes compared to the width of the interspaces are unique within *Callograptus* and the characteristics set the specimen apart from other described callograptids. The subcircular or uniform distal edge of the rhabdosome suggests that growth proceeded at essentially the same rate throughout the colony.

Callograptus sp. 2
Plate 1, figure 5; Plate 2, figure 1(?)

Material. Part (GSC 40938) of an immature rhabdosome and probably also a fragment (GSC 40939) from the distal part of a rhabdosome, both from GSC locality 53163.

Description. The immature rhabdosome has a distorted, somewhat indistinct central area. The near-circular disposition of the stipes about the central area suggests that the rhabdosome was conical in life.

The stipes are 0.3 to 0.4 mm wide; most are straight or slightly flexed. They branch by dichotomy, apparently irregularly, at intervals of 0.7 to about 7 mm. Commonly, of the stipes produced at dichotomy one is two to four times longer than the other before branching. They diverge from each other initially at 40 to 77 degrees, but turn toward each other to ultimately enclose an angle of 12 to 30 degrees. Distortion of the rhabdosome before or during preservation appears to have been a significant factor in the observed wide range in angles enclosed between two stipes formed by dichotomous branching.

The immature specimen is typified by its thin stipes, long stipe lengths before branching, and irregularity of branching.

The fragment of the distal part of a rhabdosome in the same collection has the same stipe width and irregularity in branching as the immature rhabdosome and may be the same species. The stipes turn inward toward each other after dichotomy to enclose an angle of 5 degrees or less. The stipes are separated by interspaces that are 0.4 to 0.6 mm wide.

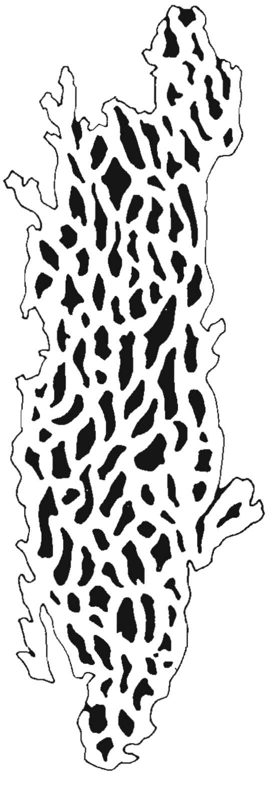
Discussion. The species differs from *Callograptus* sp. 1 in having narrower stipes and wider interspaces between the stipes. Both rhabdosomes were apparently conical in life, but the rhabdosome of *Callograptus* sp. 2 appears to have had the aspect of a more loosely woven network of stipes than that of *Callograptus* sp. 1.

Genus ***Desmograptus*** Hopkinson 1875

Desmograptus sp.
Textfigure 2

Material. One rather large rhabdosome fragment (GSC 40930) from GSC locality 53168 and three small rhabdosome fragments from 53166.

Description. The largest fragment is approximately 50 mm long and 15 mm wide; the others are small shreds.



TEXTFIGURE 2
Desmograptus sp.; drawing of largest rhabdosome fragment in the collections; GSC 40930, from GSC locality 53168 (x2).

The stipes are 0.5 to 0.7 mm wide; they anastomose regularly. Stipe anastomosis forms ovoid interspaces that are 1.2 to approximately 5 mm long and 0.5 to 1.5 mm wide. Most interspaces are 2 to 3 mm long and 0.7 to 1.0 mm wide. Thecae are indistinct. No demonstrable proximal part of the rhabdosome was found.

Discussion. Because only rhabdosome fragments are available, only a few characteristics may be described. The regularity of stipe anastomosis indicates that the rhabdosome fragments are desmograptids.

Genus ***Dictyonema*** Hall 1851

Dictyonema sp. 1

Plate 1, figures 1, 3, 4; Textfigure 3A, B

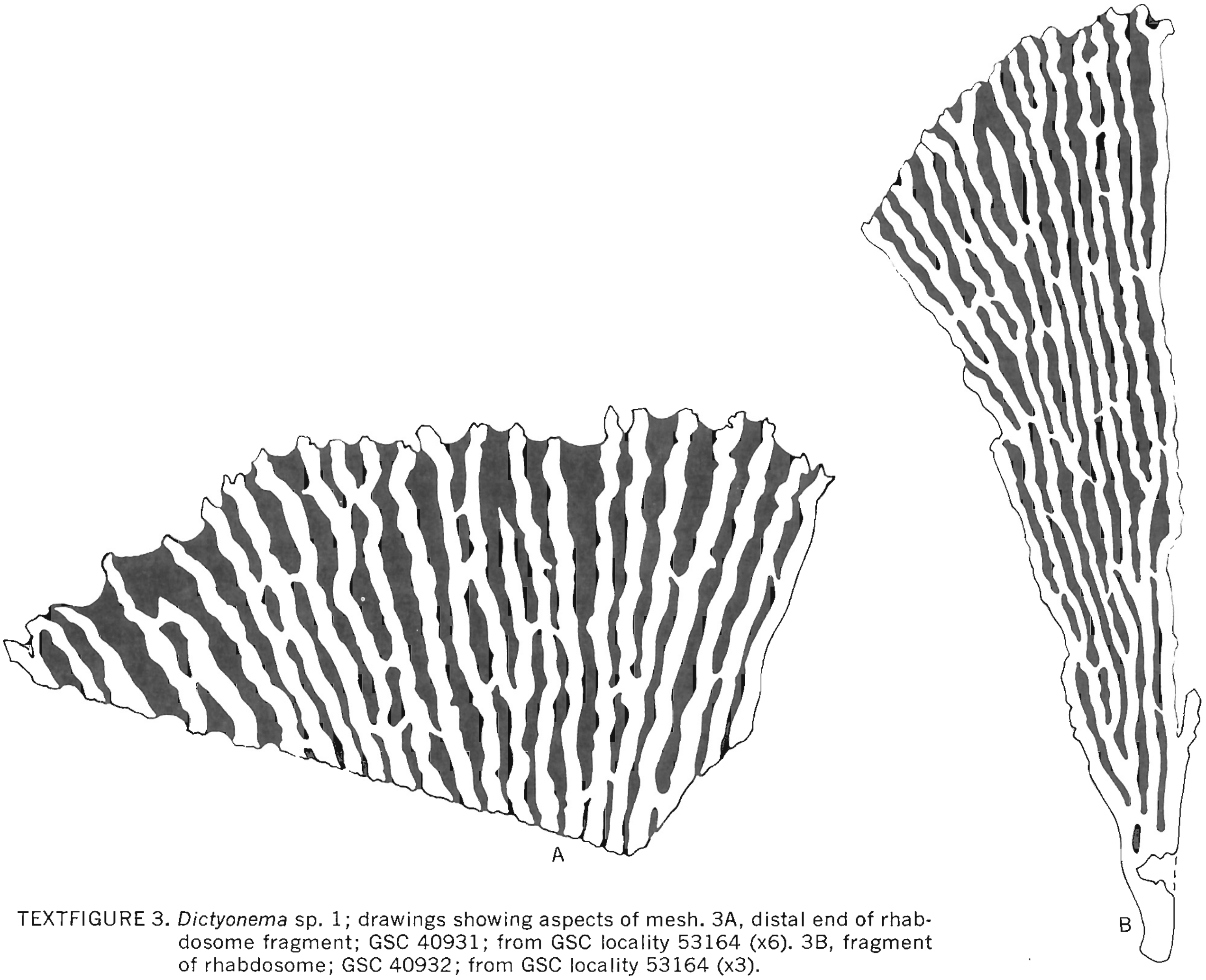
Material. About 45 rhabdosome fragments and immature rhabdosomes (including GSC 40931–40934) from GSC locality 53164 and at least three fragmentary rhabdosomes (including GSC 40935) from locality 53160.

Description. Fragments are up to 60 mm long. Two immature rhabdosomes with the proximal regions moderately well preserved are nearly complete circles, suggesting that the rhabdosomes had a conical shape in life position. A small bulb-like structure appears to be present at the centre of one of the two. Although the preservation is such that branching patterns are not distinct, the proximal areas of both rhabdosomes indicate that branching took place relatively rapidly from a central stipe or stipes.

The stipes bifurcate in the most proximal parts of the rhabdosomes in intervals of 2 to 3 mm. The next stipe bifurcations take place within intervals of 1.0 to 12.3 mm, succeeding ones occur irregularly at a distance of at least 4 mm from a previous bifurcation. The stipes turn somewhat abruptly after bifurcation to become essentially subparallel.

The stipes are 0.35 to 0.45 mm wide and are separated by interspaces that are commonly about the same width as the stipes, although some of the interspaces are as narrow as 0.25 mm. The stipes are spaced at about 6 to 7 in 5 mm in the medial and distal parts of the rhabdosome.

Dissepiments are 0.2 to 0.3 mm wide and are rare in the proximal part of the rhabdosome, being spaced commonly at 1 in 10 mm. They are more closely spaced in the distal parts and may be as close as 5 or 6 in 10 mm in some areas,



TEXTFIGURE 3. *Dictyonema* sp. 1; drawings showing aspects of mesh. 3A, distal end of rhabdosome fragment; GSC 40931; from GSC locality 53164 (x6). 3B, fragment of rhabdosome; GSC 40932; from GSC locality 53164 (x3).

but as few as 2 or 3 dissepiments may be present in 10 mm in certain areas in the distal parts of the same rhabdosomes.

Thecae are indistinct. Apparent autothecae seem to have been long tubes that are inclined to the stipe axis at 10 to 18 degrees. Small sections of some rhabdosome fragments have been partly pyritized, and the stipes stand out in low relief. Such fragments reveal traces of what may have been bithecae. The possible bithecae appear to be short and to have curled partly around the autothecae.

Many stipes in the rhabdosome fragments have a "wavy" or "zig-zag" aspect. This aspect of certain stipes apparently results from the thecal budding pattern. One or perhaps more autothecae appear to have developed from its (or their) predecessors at a low angle. The development was first to one side and then to the other of the general direction of the stipe axis.

Discussion. These specimens are characterized by irregularity in stipe bifurcation, relatively long distances between bifurcations in most stipes, and irregularity in distribution of the dissepiments. Dissepiments are so irregularly distributed that some specimens and even certain parts of some rhabdosomes appear more similar to *Callograptus* than to *Dictyonema*. The generally "wavy" or "zig-zag" aspect of many stipes in most specimens is a unique feature of these specimens.

Dictyonema sp. 2

Plate 2, figure 2

Material. One specimen (GSC 40936) from GSC locality 53163.

Description. The specimen is essentially fan-shaped, 35 mm long and 28 mm wide at greatest width. A small bulb-like structure at the apex is 1.5 mm long and 1.0 mm wide. A stout stem-like structure 1.5 mm wide and approximately 1 mm long appears to originate from the bulb-like structure. Stipes arise by dichotomy. Three stipe bifurcations take place at intervals of 0.5 to 1.7 mm from the preceding bifurcation in the proximal part of the rhabdosome. The stipes apparently remained unbranched throughout the remainder of the rhabdosome after the last dichotomy. Poor preservation of the specimen makes recognition of stipe branching uncertain.

The stipes are 0.45 to 0.55 mm wide and are essentially parallel in the distal part of the rhabdosome; interspaces are 0.3 to 0.4 mm wide.

The rare dissepiments are 0.1 to 0.4 mm wide and spaced at 1 to 3 in 10 mm in the distal part of the rhabdosome and at 1 or 2 in 15 mm in the proximal part.

Discussion. The long unbranched length of the stipes and the uniform width of the stipes throughout the rhabdosome are characteristic features of the specimen. The specimen may have been part of a larger rhabdosome, but poor preservation makes determination of this relationship unclear. In comparison with *Dictyonema* sp. 1, this specimen has thinner interspaces between the stipes and slightly wider stipes. The presence of some dissepiments (although rare) and a shrub-like aspect of the whole rhabdosome suggest that its relationships lie with *Dictyonema*.

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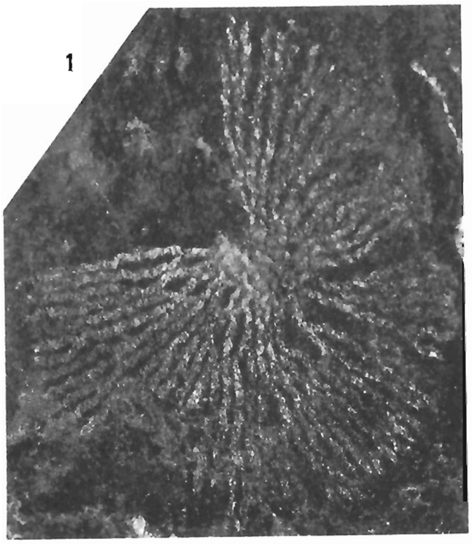
PLATE 1

1



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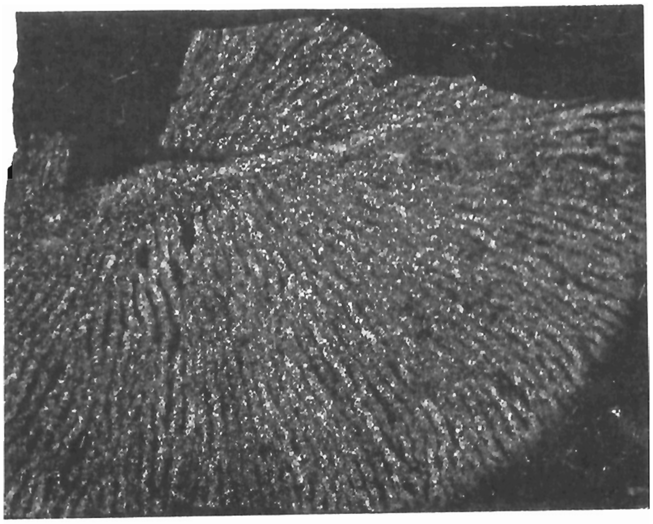

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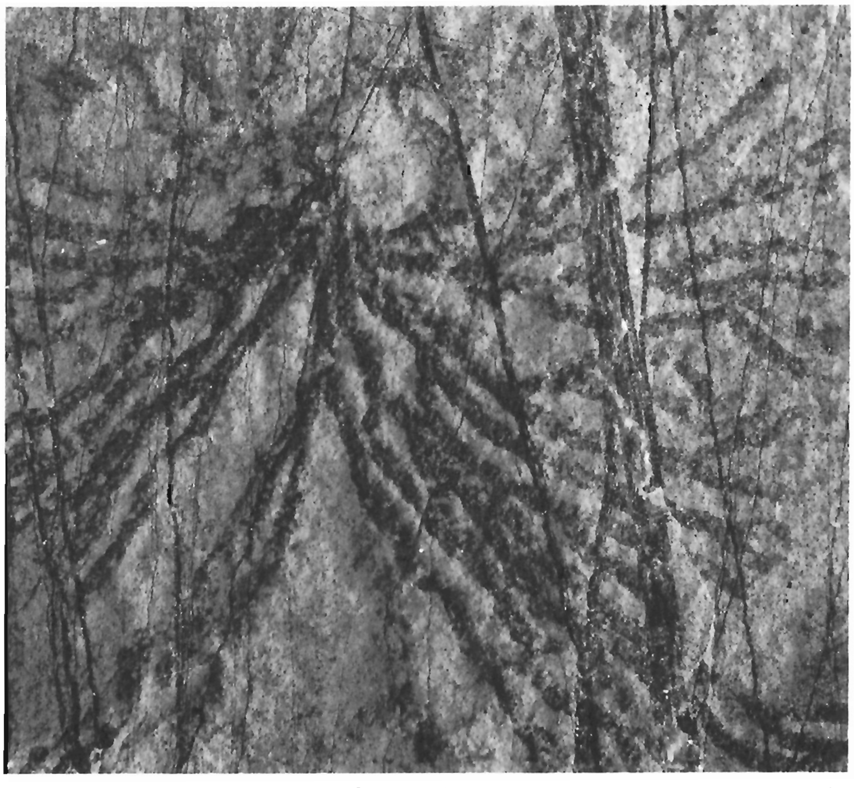

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Dictyonema sp. 1 (*see also* Textfig. 3A, B) (Page 6)

Figure 1. Proximal part of rhabdosome showing near-circular appearance of that part of rhabdosome preserved in flattened position; GSC 40934 from GSC loc. 53164; x2.

Figure 3. Rhabdosome fragment showing stipe arrangement in medial and distal parts of rhabdosome; GSC 40933 from GSC loc. 53164; x 2.5.

Figure 4. Rhabdosome fragment with dissepiments preserved; GSC 40935 from GSC loc. 53160; x2.5.

Figure 2. *Callograptus* sp. 1. The most nearly complete rhabdosome; GSC 40937 from GSC loc. 53164; x2.5. (Page 5)

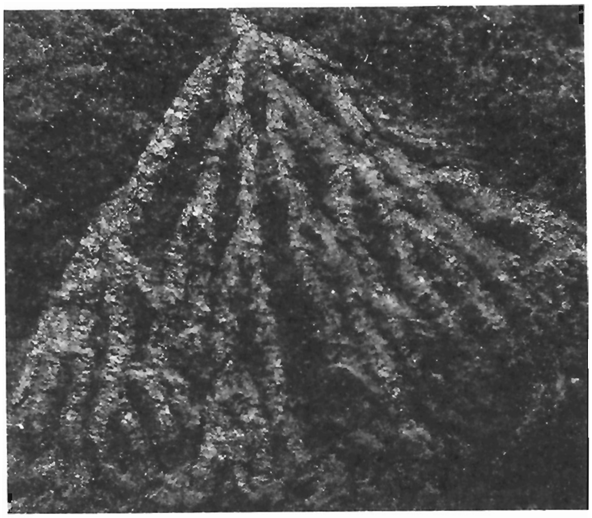
Figure 5. *Callograptus* sp. 2. Proximal part of rhabdosome; GSC 40938 from GSC loc. 53163; x5. (Page 5)

1

2

Figure 1. *Callograptus* sp. 2(?). Fragment from distal part of rhabdosome; GSC 40939 from GSC loc. 53163; x5. (Page 5)

Figure 2. *Dictyonema* sp 2. The most nearly complete rhabdosome; GSC 40936 from GSC loc. 53163; x5. (Page 7)



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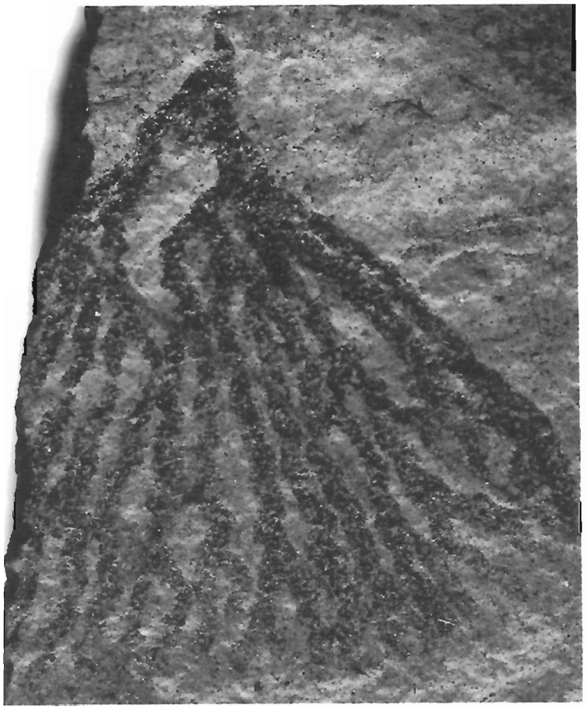

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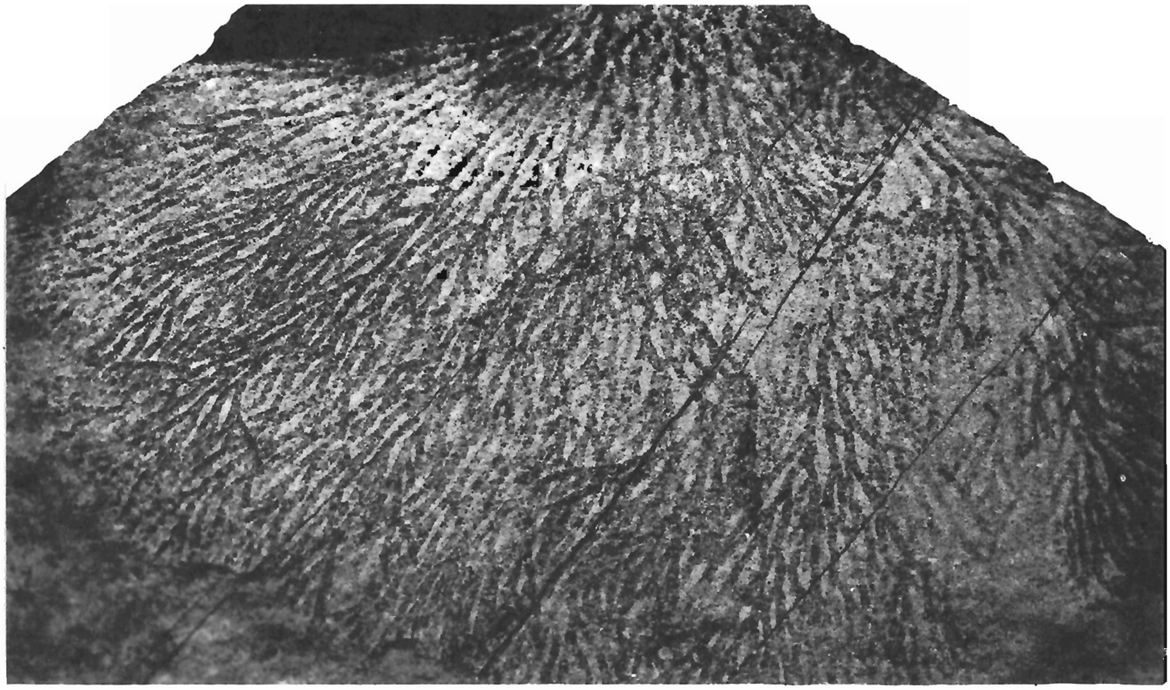
Figure 1. *Dendrograptus* sp. 5. The single rhabdosome; GSC 40944 from GSC loc. 53159; x5. (Page 4)

Figure 2. *Dendrograptus* sp. 3. The single rhabdosome, note small bulb-like structure at base of specimen; GSC 40942 from GSC loc. 53160; x5. (Page 3)

Figure 3. *Dendrograptus* sp. 2. The single rhabdosome, in the collection; GSC 40941 from GSC loc. 53163; x5. (Page 3)



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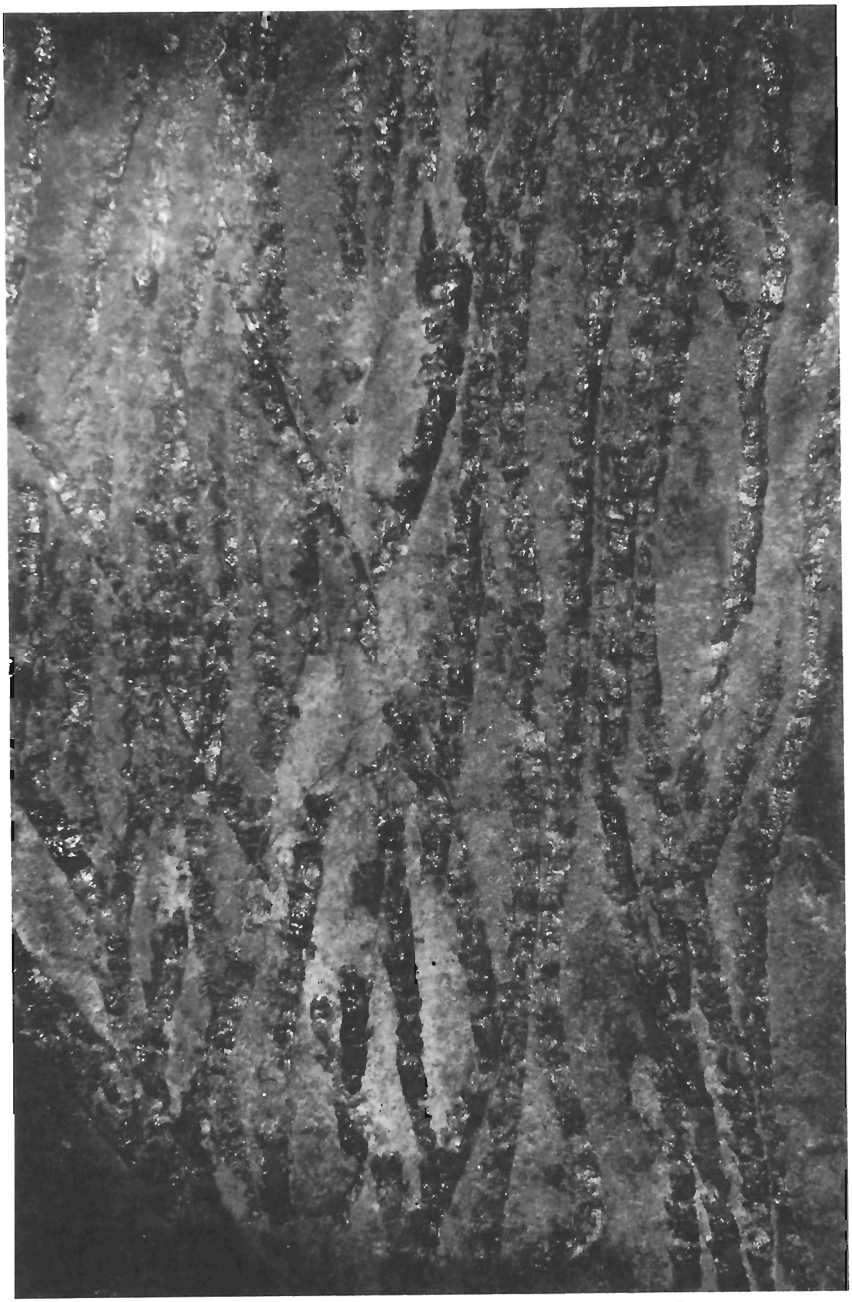
Dendrograptus sp. 1
(Page 3)

Figure 1. The single specimen in the collections; GSC 40940 from GSC loc. 53163; x2.5.

Dendrograptus sp. 4
(Page 4)

Figure 2. The single rhabdosome; GSC 40943 from GSC loc. 53160; x10.



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Dendrograptus sp. 6 (Page 4)

Figure 1. A major part of the most complete rhabdosome fragment; GSC 42538 from GSC loc. 53159; x5.

Figure 2. Fragment from possible distal part of rhabdosome showing branching and thecae; GSC 42537 from GSC loc. 53159; x5.

BIOSTRATIGRAPHY AND PALEOECOLOGY OF THE *ATRYPELLA* COMMUNITY, UPPER SILURIAN DOURO FORMATION, DEVON ISLAND, DISTRICT OF FRANKLIN

by R.E. Smith[1]

Abstract

Two measured sections of the Douro Formation of Devon Island were examined; emphasis was on the paleoecology and faunal sequence. *Atrypella* may have lived with its posterior end embedded in the muddy substrate of a somewhat restricted, shallow-water environment. Intermittent, low-velocity currents caused disarticulation of brachiopods of the *Atrypella* community and resulted in shells being swept in from adjacent communities. Influxes of argillaceous material were fairly common. The *Atrypella* community contains abundant fossils but has a small faunal diversity; most of the community is composed of *Atrypella scheii*, *Protathyris* spp., and *Howellella* sp.

A crude zonation may exist within various species of *Atrypella*, but more precise dating than is afforded by the brachiopods is needed to establish its validity.

Résumé

Deux coupes ont été levées sur l'île Devon, dans le but d'étudier la paléoécologie et la distribution de la faune dans la formation Douro. *Atrypella* vivait probablement en milieu peu profond et quelque peu confiné avec son extremité postérieure enfouie dans la boue. Les brachiopodes de la communauté du *Atrypella* ont été désarticulés par des courants intermittents de faible énergie et les valves libres ont été flottées à partir de régions voisines. Les apports de matériel argileux sont assez fréquents. La communauté du *Atrypella* est représentée par un grand nombre de spécimens mais peu variée, les seules espèces présentes sont *Atrypella scheii*, *Protathyris* spp., et *Howellella* sp.

Une zonation grossière peut être établie à partir des différentes espèces d'*Atrypella*, mais un contrôle précis avec d'autres faunes reste à établir.

Introduction

The primary purpose of this study was to investigate the possibility of zonation among various species of *Atrypella* and to study the paleoecology of the genus. A further objective was to study the taxonomy and paleoecology of the other brachiopods of the *Atrypella* community.

Most of the faunas described here were collected by the writer in the summer of 1971 while a member of Operation Grinnell of the Geological Survey of Canada under the leadership of J. Wm. Kerr. Most of the samples were collected from two measured sections of the Douro Formation (Textfig. 1, loc. 1; Textfig. 4, locs. 3 and 5), whose detailed stratigraphy also was studied by Morrow (1973). Section 5 is included by aerial photograph A16747-162 with the base at co-ordinates −3.6X, +4.1Y and Section 3 by aerial photograph A16747-163 with the base at co-ordinates +0.7X, −1.1Y. Specimens of *A. prunum* (Dalman) were collected by A.R. Ormiston from Cornwallis Island in 1960.

Large samples were collected wherever possible within the measured sections to provide sufficient data to allow inferences concerning biostratigraphy, phylogeny, and paleoecology. Some of the described specimens are from collections with little or no stratigraphic control and, therefore, are of limited usefulness for zonal purposes.

Acknowledgments

J. Wm. Kerr and the Geological Survey of Canada provided logistic support for the field work and D.W. Morrow assisted in the collection of the samples. The faunas described were prepared and studied under the supervision of A.J. Boucot and J.G. Johnson, Oregon State University. R. Thorsteinsson and W.W. Nassichuk of the Geological Survey of Canada provided valuable guidance during the study.

Previous Work

The earliest work on the brachiopods from the Canadian Arctic that now are known as *Atrypella* was by Salter (1852), who reported on fossils returned to England from naval expeditions made in 1850 and 1851. Per Schei, during the second voyage of the *Fram* (1898–1902), made large collections of Silurian brachiopods from his series B in Reindeer Valley on the east side of Goose Fiord, southwestern Ellesmere Island. These fossils were subsequently studied by Holtedahl (1914).

Nikiforova (1970) described numerous species of *Atrypella* from Vaigatch (the northern extension of the Urals) and presented a zonal scheme based on these species. Several other species have been described from North America and Eurasia by Nikiforova (1937, 1954, 1970), Cooper (1942), Johnson and Reso (1964), Khodalevich (1939), and Kirk and Amsden (1952).

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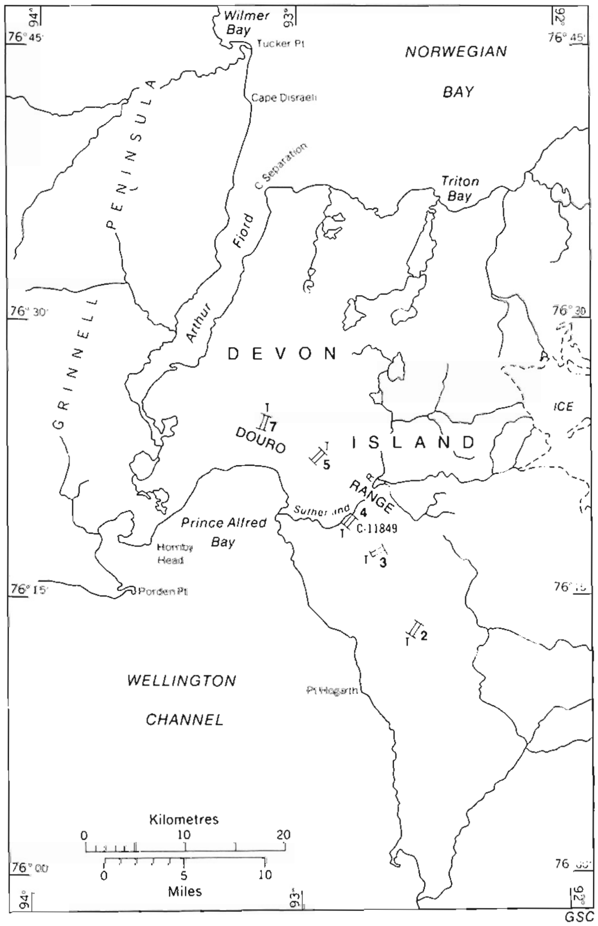


TEXTFIGURE 4. Index map for second and third papers. 5 (E504250, N8475000) and 3 (E508350, N8467500), locations of stratigraphic sections through Douro Formation; tops of sections indicated with a "T" (Smith paper). 2 (E519000, N8459000), 3 (E508350, N8467500), 4 (E505500, N8471600) and 7 (E496600, N8479500) locality on southeast bank of Sutherland River and of locations of measured sections of Devon Island Formation; tops of sections indicated with a "T" (Jackson, Kerr, and Morrow paper). Section numbers refer to stratigraphic sections described by Morrow (1973) and by Morrow and Kerr (in press).

Stratigraphy

The fossils were collected from the Upper Silurian Douro Formation in the Douro Range of northwestern Devon Island, where its thickness ranges from 311 to 1,179 feet (93–354 m) (J. Wm. Kerr, pers. com., 1974). The dominant lithology of the Douro Formation in these sections is limestone and argillaceous limestone, which are light to medium dark grey with grey and green argillaceous seams. The rocks are generally thin to medium bedded with thick beds less common. In places, particularly near the top of the Douro, the beds are very argillaceous and lumpy.

The basal contact of the Douro Formation is gradational and conformable with the underlying Cape Storm Formation (Kerr, in press), which is predominantly thin- to thick-bedded limestone, interbedded with grey-yellow, finely crystalline dolomite. The Douro Formation begins with the first predominantly brachiopod-bearing, dark grey limestone bed containing grey-green argillaceous material. It is overlain with sharp, yet conformable contact, by the Devon Island Formation which consists of approximately 500 feet (150 m) of graptolite-bearing, greyish black, silty limestone and dolomite that weather light yellow.

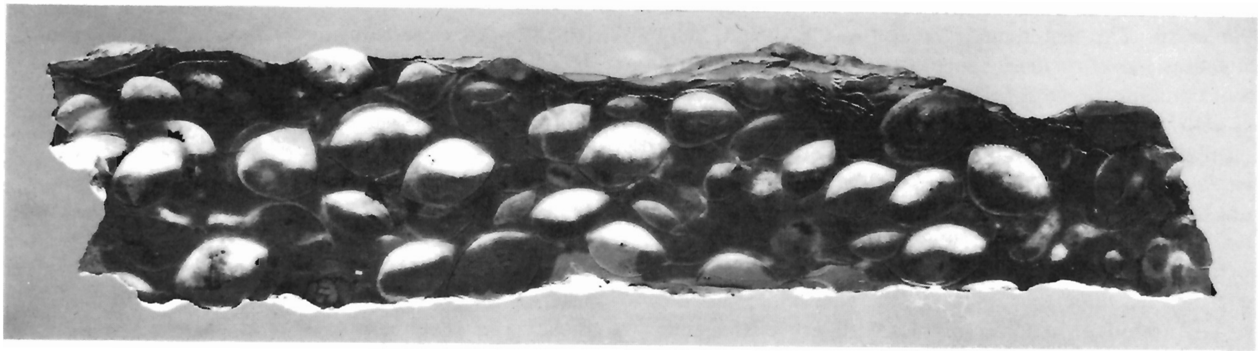
Paleoecology

Lithology

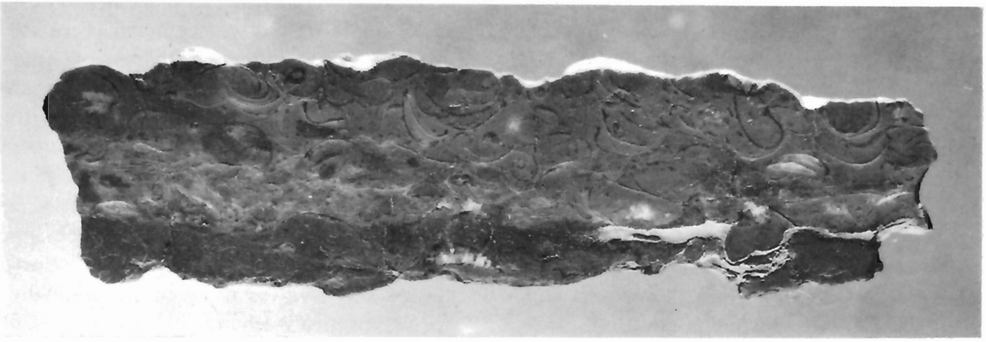
The brachiopods occur in two main rock types arbitrarily designated Types A and B. Type A is medium to dark grey, thin- to medium-bedded, lumpy, poorly indurated limestone containing numerous grey-green argillaceous seams that are composed mainly of illite, sericite, and chlorite (D.W. Morrow, pers. com., 1974). Type B is medium grey, thin-bedded, platy, well-indurated limestone with much less argillaceous material than Type A; some samples of both contain very minor amounts of pyrite. Type A generally contains a higher percentage of articulated brachiopods in the form of geopetals and contains fewer other phyla than Type B. Thicker beds of both lithologies contain less argillaceous material and only sporadic occurrences of brachiopods.

Petrographic analysis shows that the sediment in Type A is relatively undisturbed, with articulated brachiopod shells, rare ostracodes, and lime mud as the main constituents. Type B contains disarticulated and fragmentary brachiopod shells, common ostracodes, high-spired gastropods, rare crinoids, rare trilobites, echinoderm plates and spines, and elongate lime mud intraclasts (up to 5 mm long). The difference in constituents, particularly the intraclasts, demonstrates that some form of current activity took place although it may not have been vigorous. The currents tore up pieces of semiconsolidated lime mud and carried in shells from adjacent communities. Examination of shell thickness and the dentition of *Atrypella* spp. allows the suggestion that low-velocity currents would be sufficient to disarticulate the shells. The biconvex shape of the shells would contribute to their being rolled around by currents, substantially increasing the total amount of travel although the net distance may have been small.

Geopetal fabric is extremely well developed in a sample from GSC locality C-11953 of Type A lithology (Textfig. 5). In some specimens, the spiralia of the brachiopods are easily seen. Nearly all the specimens of *Atrypella* in this sample are preserved as geopetals although there are a few disarticulated specimens. The matrix is approximately 90 per cent lime mud. In Type B lithology (Textfig. 6), nearly all the valves are disarticulated. Elongate sedimentary intraclasts are evident in the lower one third of the picture and an erosional contact is visible in the lower left part. The base of the slab is essentially lime mud which is overlain by a layer of intraclasts and disarticulated brachiopod valves, the contact between the two being somewhat undulatory. In the lower right area of the slab a thin argillaceous seam is truncated about midway in the slab. In the extreme lower right-hand corner, the argillaceous seam appears to have been deflected downward as a result of loading.



TEXTFIGURE 5. Photograph of slab with *Atrypella* (GSC 34039) from GSC locality C-11953, illustrating geopetal fabric (x1).



TEXTFIGURE 6. Photograph of slab with *Atrypella* (GSC 34040) from GSC locality C-11953, illustrating fabric (x1).

Bedding is one of the most interesting features of the Douro Formation in outcrop. It has been referred to variously as nodular, wavy, and lumpy. The bedding is very undulatory and is best developed in conjunction with numerous grey-green argillaceous seams or partings. The term lumpy is favoured over nodular because the latter refers to having the shape of or being composed of nodules.

A possible explanation for the lumpy bedding is burrowing (Jack Wendte, pers. com., 1972). Presumably, soft-bodied organisms travelled slightly below the sediment-water interface, in a horizontal plane, ingesting sediment and expelling fecal pellets composed of lime mud. Such burrowing thus created bands of more consolidated sediment. Succeeding layers of sediment loaded differentially on the burrows and on the areas between the burrows and produced concave deflections in the bedding planes. The more argillaceous sediments in the non-burrowed areas were compacted more than the lime mud of the burrows. One might speculate that the organisms would have concentrated their activities in the more argillaceous layers as these may have contained a greater amount of nutrients. Some burrows are visible on slabs of the Douro Formation.

There may be a direct correlation between number of taxa in a sample and percentage of argillaceous material. The thick-bedded units are not very argillaceous and contain a very sparse fauna. Sediments with moderate and high percentages of argillaceous material contain a large number of brachiopods. However, extremely argillaceous sediments do not seem to contain as many taxa as do those with somewhat less argillaceous content and there may have been an optimum content of argillaceous material that was conducive to a flourishing population of these brachiopods.

Life and Death Assemblages

A problem in paleoecological studies is ascertaining whether the sample represents a life or death assemblage, because upon this premise depends any deductions about the life conditions of the organism. Boucot (1953) presented criteria for distinguishing between a life assemblage (undisrupted) and a current-drifted assemblage. If a high infant mortality rate among the organisms in question is assumed, the size/frequency curve will be strongly concave downward if no external forces alter the population structure before preservation. If sedimentation is rapid, the assemblage may be buried before external forces come into action. Human error may produce a skewed size/frequency curve due to the difficulty of detection and subsequent extraction of the smallest forms from the matrix. A second consideration is the ratio of articulated/disarticulated valves but some brachiopods disarticulate more easily than others because of differences in shell form, thickness, and dentition. A third consideration is the ratio of pedicle to brachial valves present. If a particular taxon is markedly either dorsibiconvex or ventribiconvex, the two valves may become differentially current sorted.

Sample C-11952b is a good example of a life assemblage. The ratio of articulated/disarticulated specimens is 3.5 for *Atrypella scheii* (Holtedahl), 7.6 for *Protathyris* spp., 1.67 for *Ferganella* cf. *F. turkestanica* Nikiforova and 0.06 for

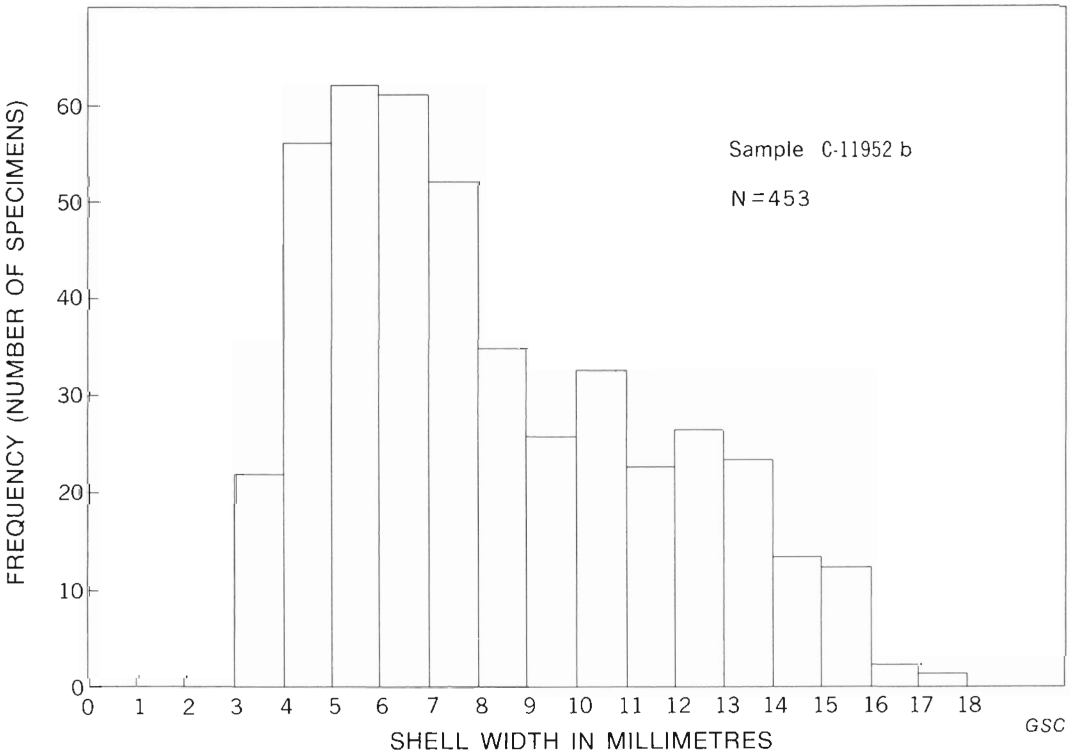
Howellella sp. The last figure, far below the others, may indicate that the *Howellella* shells were carried in from an adjacent community. Of a total of 1,003 specimens counted, 73 per cent are *Atrypella scheii*, 18 per cent are *Protathyris* spp., 1.6 per cent are *Howellella* sp. and 3 per cent are *Ferganella* cf. *F. turkestanica*. Indeterminate strophomenids account for 4 per cent and there is one gastropod, one coral, and one crinoid. The matrix of the sample contains a large proportion of argillaceous material and is poorly indurated (Type A). Ostracodes are absent from the sample but are moderately abundant in some samples with less argillaceous content.

Textfigure 7 is a size/frequency diagram of *Atrypella scheii* from a sample from GSC locality C-11952. The curve is very near to what one would expect for a normal life assemblage with a high infant mortality rate. The interval from 3 to 4 mm is anomalously low compared to the interval from 4 to 5 mm. This may be the result of difficulty in detecting and extracting specimens of such small size and/or the effects of predators. Current effects cannot be ruled out but, if present, currents are thought to have had very low velocities.

A sample from GSC locality C-11952c is an example of a typical death assemblage. The articulated-disarticulated ratios are as follows: *Atrypella scheii* 0.12, *Protathyris* spp. 0.35, *Howellella* sp. 0.03. Of 269 specimens counted, *Atrypella scheii* comprised 76 per cent, *Protathyris* spp. 8 per cent, *Howellella* sp. 11 per cent, and high-spired gastropods 5 per cent. Other death assemblages contain minor amounts of indeterminate strophomenids, trilobites, and crinoids. This sample is hard, dense, and contains very little argillaceous material (Type B lithology). An additional 58 specimens of brachiopods were too poorly preserved to be identified to generic level.

Relationship of *Atrypella* to the Substrate

Plunges were determined by measuring the angle between the bedding plane and the commissural plane of *Atrypella*, and range from zero to 90 degrees. A few specimens plunged at 90 degrees with the posterior end uppermost whereas a very high percentage had the anterior end uppermost. The specimens with the posterior end uppermost presumably underwent some current action. There seems to be a correlation between relatively steep plunge and a large percentage of articulated specimens indicating that the specimens were buried in or near life position. Conversely, a small angle of plunge seems to correlate with a small percentage of articulated specimens (Table 1). Disarticulated specimens probably were subjected to some current action with the valves likely settling to the bottom with the plane of commissure parallel to the sediment-water interface. Two samples, C-11953b and C-11956 (Table 1), are somewhat anomalous in that they exhibit a moderate plunge with a small percentage of articulated specimens, possibly because of current action and burrowing. Burrowing could have caused some valves to be re-oriented. Burning and scraping specimens and studying valves in peels and thin section show posterior thickening of the shell material. Such weighting would tend to keep individuals' beaks downward despite slight displacement caused by currents. Smaller, immature specimens of *Atrypella* are markedly less biconvex than their mature counterparts. There was sufficient room between the beaks for a pedicle to have been present which would



TEXTFIGURE 7
Size/frequency histogram of *Atrypella* from GSC locality C-11952.

have prevented movement by currents. Mature specimens of *Atrypella* are more convex and possess such incurved beaks that there was no room for a pedicle to emerge. Their size and weighted umbonal regions would have replaced the pedicle as a means for stabilization. Mature *Atrypella* seem to have lived with their beaks immersed in soft mud bottoms.

TABLE 1. *Atrypella* orientation data from Section 5.

Sample	Number of measurements	Ped. valve uppermost	Brach. valve uppermost	Aver. plunge (degrees)	A/D
C-11951	32	12	14	23	2.2
C-11952b	22	11	7	33	2.2
C-11952c	31	15	11	17	0.25
C-11953a	45	14	23	25	8.0
C-11953b	38	22	10	38	0.7
C-11953c	36	19	15	17	0.16
C-11954a	11	3	3	76	4.5
C-11954b	30	10	13	52	4.0
C-11955a	40	26	13	4	0.1
C-11956	34	16	12	2.7	0.7

A refers to articulated specimens
D refers to disarticulated specimens

Fossil "Nests"

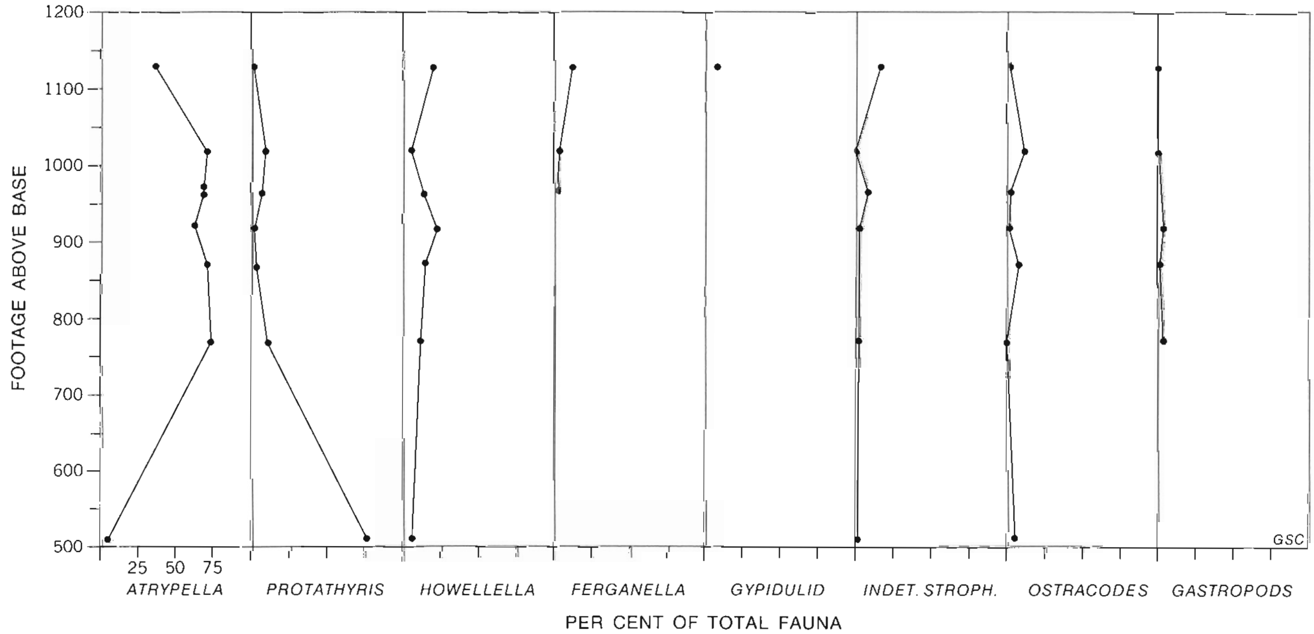
In the Douro Formation, life assemblages occur both in extremely argillaceous sediments and as clusters or "nests." Several explanations for this phenomenon have been discussed (Rudwick, 1970). One of them is that the fossils were attached to a stone or similar object, presumably by their pedicles. The writer has seen no evidence for this. A second explanation is that the brachiopods were attached to some form of material such as ascidians that normally would not be preserved in the fossil record. The shells would fall to the bottom and be buried with no record of their attachment. This may have been true for immature forms of *Atrypella*, but not for mature forms because they apparently possessed no pedicle.

Atrypella may have lived in colonies in minor depressions on the sea floor. Immature forms may have attached themselves to larger ones and thus escaped removal by current activity. An influx of sediment could have filled the depressions and buried the brachiopods in or near life position. The depth of overlying sediment could have been sufficient so that later currents did not disrupt the shells.

Relative Percentages of Faunal Constituents

In order to examine the variation in composition of the *Atrypella* community with stratigraphic position within Section 5, total faunas were counted and percentages computed for each taxon (Textfig. 8). The most striking feature is the upward replacement of *Protathyris* by *Atrypella* as the dominant constituent. At 504 feet (154 m) above the base of the section, *Protathyris* amounts to 76 per cent of the total fauna and *Atrypella* 6 per cent. At 774 feet (237 m), *Atrypella* amounts to 74 per cent and *Protathyris* 13 per cent. *Atrypella scheii* is the most abundant brachiopod in the section above this level and *Protathyris* spp. are present only in small numbers. *Howellella* sp. occurs in every sample examined and is a minor but noteworthy element. *Ferganella* and a gypidulid are very rare and occur only near the top of the formation. Ostracodes also comprise a minor but persistent element. Indeterminate strophomenids also are rare as are gastropods, which occur only in the upper two thirds of the section.

At the top of the section there is a decrease of *Atrypella*, *Protathyris*, and ostracodes, with a corresponding increase in *Howellella* sp., *Ferganella*, indeterminate strophomenids, trilobites, abundant crinoidal debris (*see* Appendix 1), and a gypidulid. This change is interpreted as a shift from the low diversity, quiet-water *Atrypella* community to a low diversity, rougher water community. *Howellella* sp. and

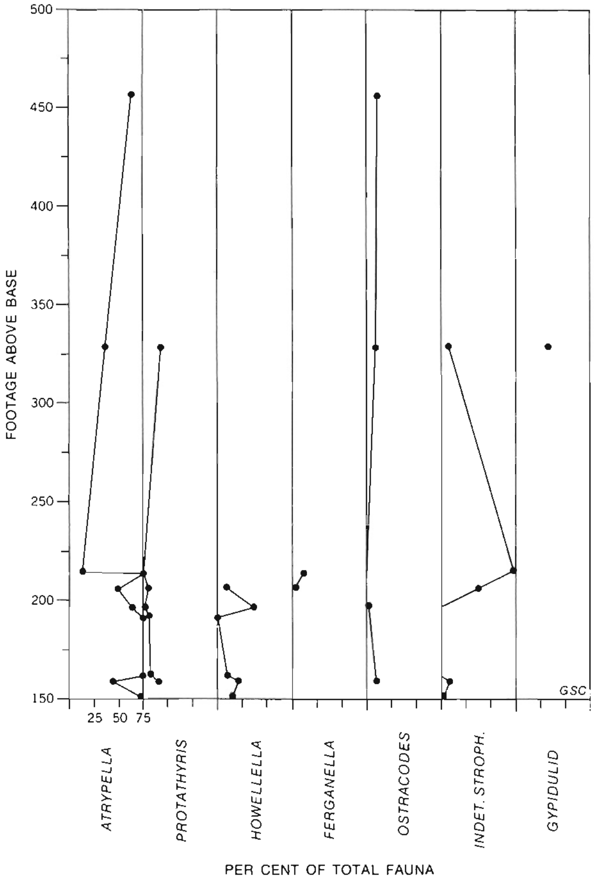


TEXTFIGURE 8. Percentage distribution of faunal elements in Section 5.

Ferganella both possess relatively thick shells and dental plates and probably were able to withstand a greater degree of turbulence than was the thinner shelled *Atrypella*.

Prediction of slightly deeper water conditions at the top of the formation is consistent with a scheme proposed by Boucot (pers. com., 1972). He finds a *Gypidula* community in a deeper position than the *Atrypella* community, in addition to designating the *Gypidula* community as a rough-water community.

In Section 3, sampling began at a horizon 152 feet (46 m) above the base (Textfig. 9) because of very poor stratigraphic control in the lower part of the section (as in Section 5). At this level, *Atrypella* is the dominant member of the fauna and *Protathyris* is less common. *Howellella* sp. and *Ferganella* are restricted to the lower part of the section. Ostracodes show a gradual increase in relative abundance from bottom to top, but the number of specimens of all taxa per sample decreases upward as well. Indeterminate strophomenids are rare, but at 216 feet (65 m) they constitute nearly 80 per cent of the total megafauna. This trend is accompanied by a corresponding decrease in *Atrypella* to 15 per cent. The gypidulid is present at only one level where it accounts for 31 per cent. Trilobites occur at the top of the formation and account for 11 per cent of total fauna. Abundant crinoid debris is present at the top of the formation as in Section 5. However, there the total megafauna is very small (17 specimens) so that the figure may be misleading. The two sections show some similar faunal trends, but differences are readily evident. Poor control in certain parts of the sections is undoubtedly responsible for some of these discrepancies. However, environmental factors possibly were largely responsible for the differences. There is a general trend of decreasing size (length, width, thickness) of *Atrypella* progressing up-section.



TEXTFIGURE 9. Percentage distribution of faunal elements in Section 3.

Section 5 has a total thickness of 1,179 feet (354 m) and Section 3 has 459 feet (138 m), less than half of the former. Section 3 contains more pyrite and a smaller total of specimens per sample than Section 5; the argillaceous matter is darker and may be more carbonaceous. Section 3 may represent a more euxinic facies in which the sedimentation rate was slower than in Section 5 and conditions were not the best for *Atrypella scheii*.

Community Ecology

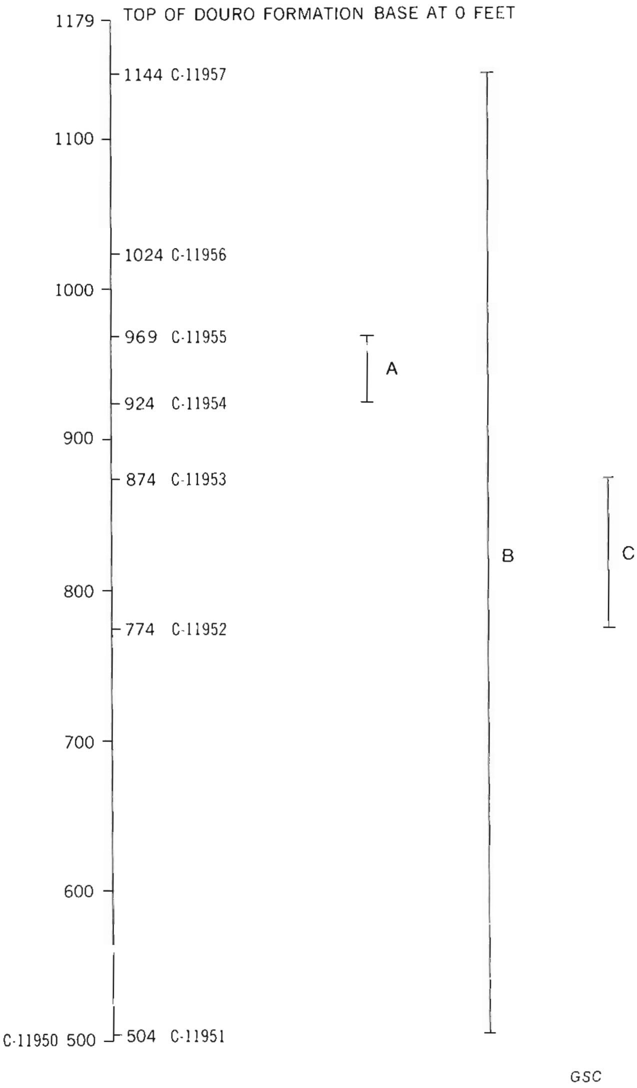
The *Atrypella* community, characterized by small diversity and high abundance of fossils, flourished in a quiet, shallow-water, subtidal, semi-restricted environment. The regional slope was low and the sedimentation rate was slow with periodic influxes of argillaceous material. The community consists predominantly of *Atrypella scheii* (Holtedahl), *Protathyris* spp., and ostracodes. *Howellella* sp. is somewhat of an anomaly in that it usually occurs disarticulated; it may be a member of an adjacent community. The various faunal constituents were tolerant of some turbidity, but not of excessive sedimentation which could have been responsible for their death and burial. The sediments were subject to burrowing by soft-bodied organisms, presumably worms, which probably fed on nutrients contained in the argillaceous sediments. Periodic currents of low velocity disrupted the normal living conditions and resulted in minor erosional surfaces and a high degree of disarticulation among members of the *Atrypella* community. These currents may have been generated by storm waves or may have been due to tidal effects. Because the two main components of the community are biconvex, they would have rolled around on the sea floor under the influence of these currents. Probably the currents were sporadic and not always from the same direction, which could have resulted in a large amount of disarticulation without the fauna being moved far from its original habitat. This type of fauna and lithology is known to occur over a large region of the Arctic Archipelago; with very uniform carbonate stratigraphy, the regional slope can be assumed to have been negligible. With a low-lying land surface with small inclination, very irregular shorelines could develop (Boucot, 1970), producing indistinct environmental and community boundaries both vertically and laterally within the rock record. It may be that the variations within the *Atrypella* community and the different subspecific forms of *A. scheii* resulted from slightly different environments.

Zonation of *Atrypella*

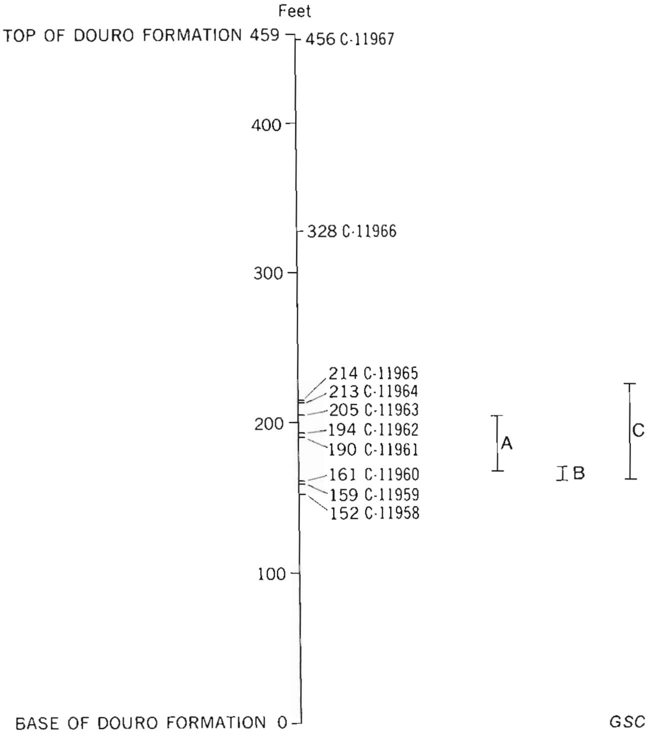
North America

Age. Boucot *et al.* (1965) reported the range for North American *Atrypella* as Late Silurian to Early Devonian. One of the oldest occurrences of *Atrypella*, designated late Wenlock, was reported by Boucot (*in* Berry and Boucot, 1970, p. 126) to be from the east side of Black Island, Newfoundland. Subsequent examination by the writer has revealed that the specimens are not *Atrypella*, but an undescribed smooth atrypacean genus. However, *Atrypella* sp. has been reported from upper Wenlock beds of the Roberts Mountain Formation, Nevada (J.G. Johnson, pers. com., 1973). Nowhere in North America is *Atrypella* known to occur in the Lower Devonian and it seems probable that the upper limit of the range of North American species of *Atrypella* is within the Pridolian.

Zonation. Most recorded occurrences of this genus in North America are not from measured sections and are of limited use in establishing any sort of zonation within the genus itself. In the Douro Formation of Devon Island, a crude zonation seems to exist within the forms A, B, and C of *Atrypella scheii* (Holtedahl) (Textfigs. 10, 11). Form A has a limited range within the sections; forms B and C seem to have longer ranges. However, the ranges are not consistent from section to section and there is difficulty in distinguishing between immature specimens of forms A and C. The forms may be environmentally controlled and therefore of little or no use for zonal purposes.



TEXTFIGURE 10. Stratigraphic ranges of *Atrypella scheii*, forms A, B, and C, in the Douro Formation (Section 5).



TEXTFIGURE 11. Stratigraphic ranges of *Atrypella scheii*, forms A, B, and C, in the Douro Formation (Section 3).

Atrypella phoca (Salter) has been reported from Member C of the Read Bay Formation of Cornwallis Island (Thorsteinsson, 1958); the age of this species is latest Ludlow or early Pridoli. To the writer's knowledge, *Atrypella phoca* does not occur below this horizon.

Atrypella scheii Kirk and Amsden *non* Holtedahl, reported from USGS locality 2689 (Kirk and Amsden, 1952, p. 53) in southeastern Alaska, appears to be a younger form than *A. phoca*. Originally reported as Late Silurian, the fauna from locality 2689 is now known to be of Pridolian age based on the presence of *Schizophoria* (J.G. Johnson, pers. com., 1972). This Alaskan *Atrypella* is different from any form of *A. scheii* encountered in the Douro Formation. In addition, specimens collected from Prince of Wales Island by R. Thorsteinsson in 1972 (GSC loc. C-8245) bear a remarkable resemblance to the Alaskan form of *A. scheii*. The age of C-8245 is definitely post-Ludlow and probably Pridoli as indicated by the presence of *Icriodus* sp. (R. Thorsteinsson, pers. com., 1972), but at present a precise age assignment is not possible.

Specimens of *Atrypella prunum* (Dalman) have been collected from the Cape Phillips Formation of Cornwallis Island but their stratigraphic distribution with regard to graptolite zones has not yet been established. Kozlowski (1929, p. 176), in describing the form from Polish Podolia, stated "*A. prunum* est tout-a-fait rare en Podolie polonaise se presentant seulement à la base des calcaires de Skala," and an age assignment as young as Pridoli seems possible. However, *A. prunum* (Dalman) is found also in the Hemse

Group (Ludlow) of Gotland. The species may be Ludlow to early Pridoli in age, but its stratigraphic relationship to *A. phoca* and to *A. scheii* Kirk and Amsden *non* Holtedahl has not yet been established.

In conclusion, zonation of North American *Atrypella* is somewhat sketchy at present. More data from measured sections are needed, coupled with precise ages using conodonts and graptolites.

Eurasia

When attempting to establish any zonation within the species of *Atrypella* reported from these regions, there are several problems that are not solved easily. Newer stratigraphical studies have assigned different ages to certain strata. The quality of the photographs makes comparison of some of the forms difficult and at times nearly impossible. Pictures of the internal structures of the various species are not included in some of the publications. In addition, earlier publications by Khodalevich, (1939); and Nikiforova, (1954) incorrectly used *Lissatrypa* synonomously with *Atrypella*. The following designations of *Atrypella* for specimens previously assigned to *Lissatrypa* are by examination of the published illustrations and, wherever possible, study of the descriptions of the internal structures.

Age. Khodalevich (1939) figured several forms of "*Lissatrypa*" which he said occurred in the Wenlock of the eastern slope of the Urals. "*L.*" *turjensis* Khodalevich is *Atrypella*-like, but possesses a fold that is more pronounced than in most species of *Atrypella*. The species does not show inner hinge plates that are characteristic of *Lissatrypa*. "*Lissatrypa*" *camelina* (Buch) also is similar in external and internal characteristics to *Atrypella* and probably is *Atrypella*. Nikiforova and Obut (1965) assigned strata containing *A. camelina* to the lower Ludlow. Nikiforova (1970) cited *A.* cf. *A. kuschvensis* (Tschernyschew) as occurring in the Vaigatch Horizon which is reported to be Lower Devonian. However, beds below the horizon of *A.* cf. *A. kuschvensis* have not been proven to be of Early Devonian age and the range for this genus may be late Wenlock to Pridoli.

Zonation. The lower Ludlow is characterized by *Atrypella camelina* (Buch), but this form ranges into the Pridoli (Nikiforova and Obut, 1965). *Atrypella linguata* (Buch) also is found in the Ludlow (Nikiforova, 1937). *Atrypella phoca* occurs in the upper Pridoli of Vaigatch in the Greben Horizon (Nikiforova, 1970). In the Pridoli of Vaigatch, Nikiforova (1970) also reported *Atrypella* cf. *A. kuschvensis*. Khodalevich (1939) reported *Atrypella vagranica* (Khodalevich) from the Marginalis Beds of the eastern slope of the Urals. These beds are known to range into the Lower Devonian, but the writer is unaware of what horizon within the Marginalis Beds yielded the listed specimens. *Atrypella prunum* (Dalman) occurs in the Hemse Group of Gotland, but the stratigraphic relationship of this species with other *Atrypella* species in these regions is not known. *Atrypella gigas* (Khodalevich, 1939) may be a geographic variation of *A. prunum* (Dalman), but its stratigraphic position within the Marginalis Beds is not known to this writer. *Atrypella linguata* (Buch) may be similar to *A. scheii* form B (this paper), but lack of knowledge of internal structures hinders positive identification. Data from measured sections as well as ages utilizing graptolites and conodonts would help clear up the uncertainties within the Eurasian zonation of *Atrypella*.

Systematic Paleontology

Phylum **BRACHIOPODA**

Suborder *ATRYPIDINA* Moore 1952

Subfamily SEPTATRYRPINAE Kozlowski 1929

Genus ***Atrypella*** Kozlowski 1929

Type species. *Atrypa prunum* Dalman 1828.

Atrypella prunum (Dalman 1828)

Plate 6, figures 1–6; Textfigure 12

Atrypa prunum Dalman 1828, p. 133, Pl. V, fig. 2 (synonymy *in* Nikiforova, 1954).

Material. Figured specimens USNM 211560–211562 and 23 additional specimens from USNM loc. 12671, Cape Phillips Formation, Cornwallis Island.

Discussion. Species characterized by its large size, elongate outline, and by the development of the ventral sulcus into a tongue-like process. This species occurs in the Hemse Group of Gotland and the "calcaires de Skala" of Podolia (Kozlowski, 1929). It occurs also in the Grinchuk Beds of the Malinovtsky Horizon of Podolia (Nikiforova, 1954).

Exterior. Outline elongate, oval; dorsibiconvex in lateral profile. Interarea lacking. Ventral beak incurved and impressed on dorsal umbo. Large specimens lack foramen; delthyrium not observed. Cardinal angles obtuse; maximum width occurs posterior to midlength. Shallow ventral sulcus developed anteriorly into tongue-like process; dorsal fold developed anteriorly, low, subrectangular in cross-section. Fine, concentric growth lines confined to anterior regions.

Interior. Hinge teeth stout, elongate in cross-section. Delthyrial cavity yoked. Prominent trapezoidal platform is site of diductor tracks. Vascula media project anteriorly. Sockets deep and elongate; outer hinge plates discrete and divergent. Low myophragm confined to umbo. Spiralia dorsomedially directed and consist, in large specimens, of fourteen to fifteen whorls.

Comparison. This species resembles *A. carinata* (Johnson and Reso, 1964, Pl. 20, figs. 18–26), but is larger in all dimensions and more elongate. *Atrypella carinata* does not possess as strong a deflection in the anterior commissure as does *A. prunum*. It resembles *A. penitus* (Khodalevich, 1939, Pl. 20, fig. 5).

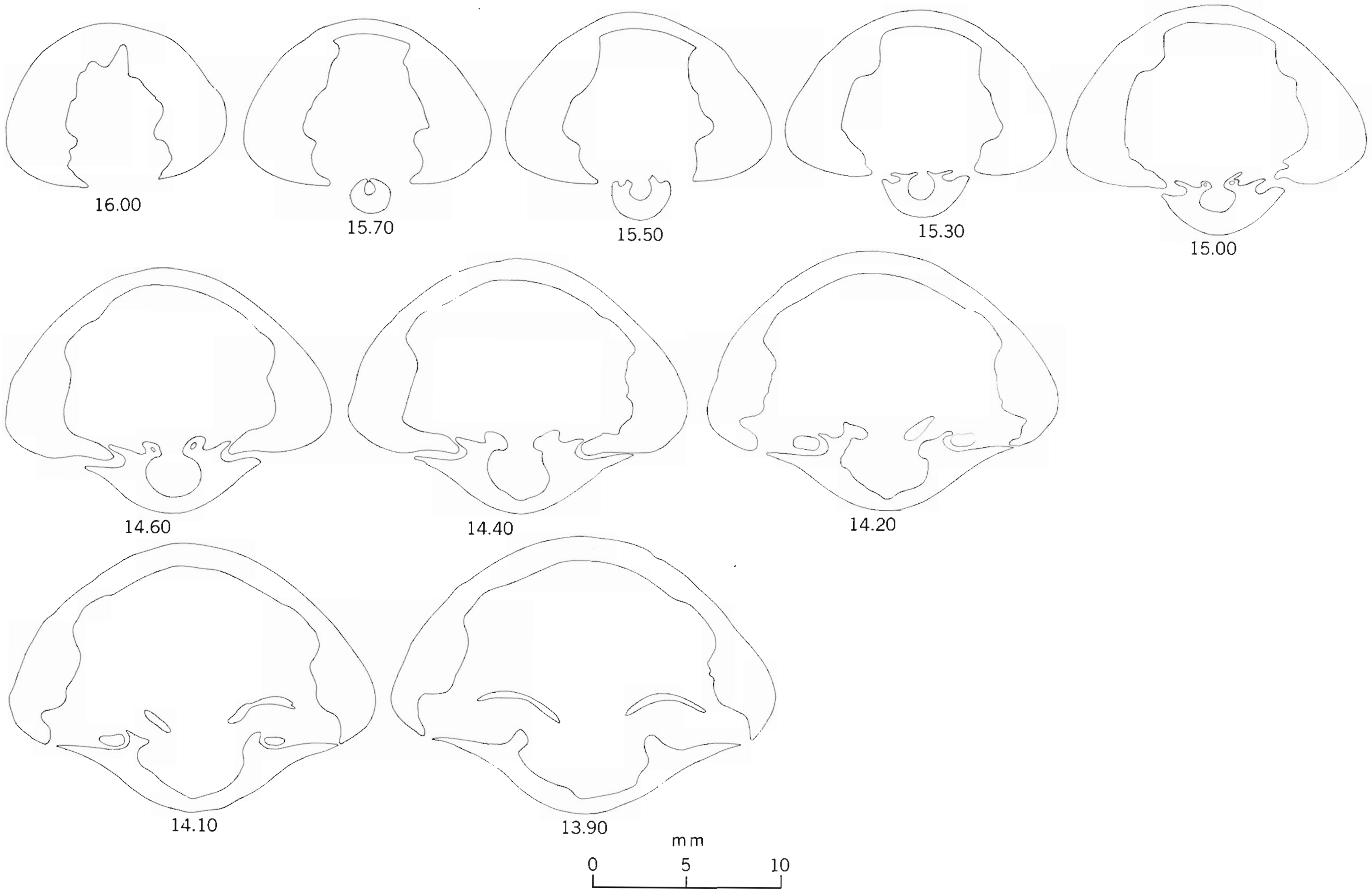
Atrypella phoca (Salter 1852)

Plate 6, figures 7–12; Textfigure 13

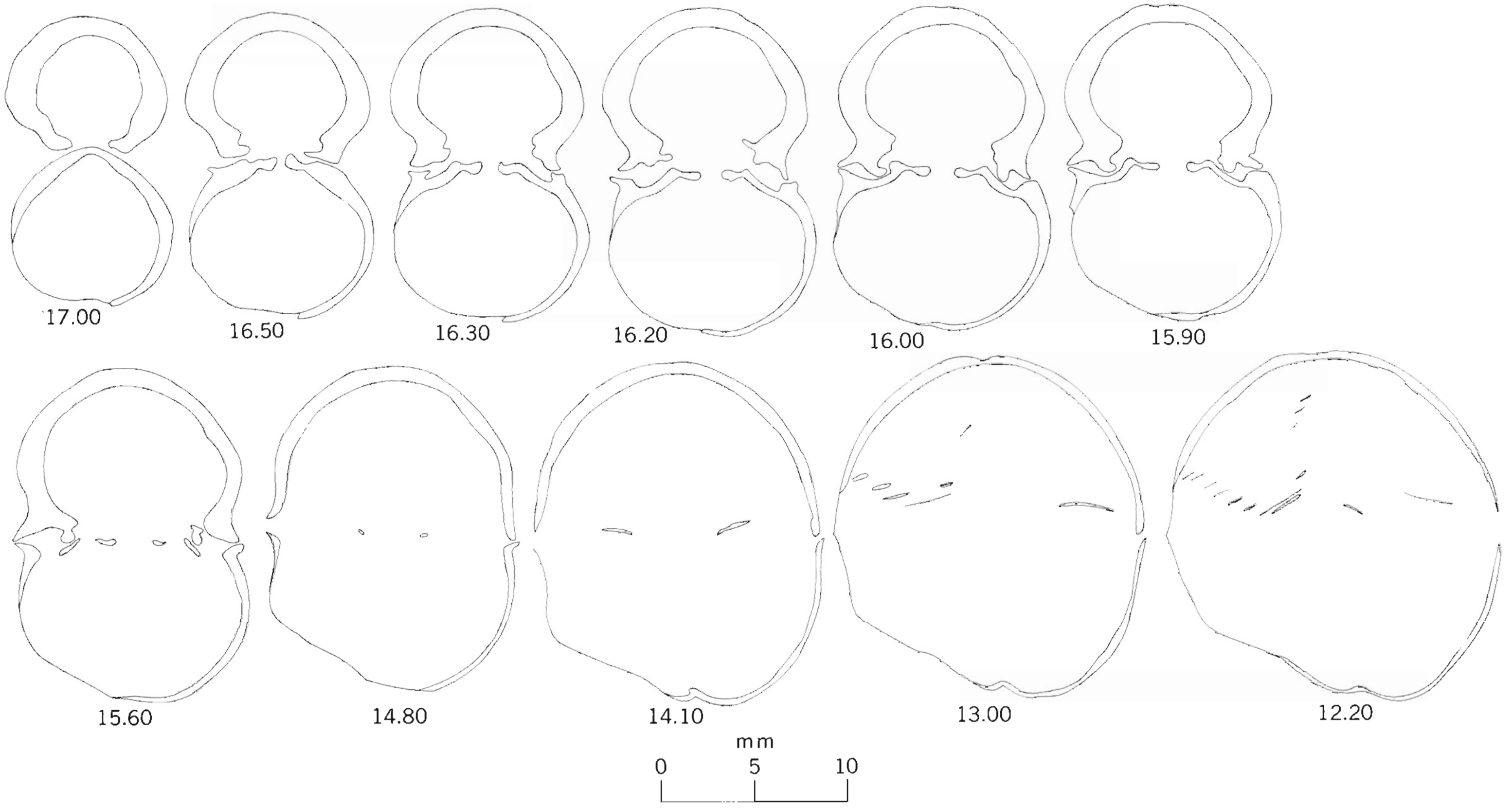
Rhynchonella phoca Salter, 1852, Pl. 5, figs. 1, 2, 3.

Material. Figured specimens GSC 34041, 34042, and 34057 from GSC locality C-33721; Read Bay Formation, Prince of Wales Island.

Discussion. This species is strongly globose and possesses a



TEXTFIGURE 12. Drawings of acetate peels from serial sections of *Atrypella prunum* (x3). Highest numbers (mm) closest to posterior end of specimen. USNM 211562, USNM locality 12671, Cornwallis Island.



TEXTFIGURE 13. Drawings of acetate peels from serial sections of *Atrypella phoca* (x2.5). Highest numbers (mm) are closest to posterior end of specimen. GSC 34057, GSC locality C-33721, Prince of Wales Island.

median furrow in both valves which true *A. phoca* also possesses. *Atrypella phoca* is known to occur in Member C of the Read Bay Formation, Cornwallis Island (Thorsteinsson, 1958) and also in the upper Pridoli of Vaigatch, USSR (Nikiforova, 1970).

Exterior. Outline suboval to subpentagonal; dorsibiconvex in lateral profile. Interarea lacking; hinge line short and curved. Large specimens lack foramen; delthyrium not observed. Cardinal angles obtuse; maximum width slightly posterior to midlength. Shallow ventral sulcus developed anteriorly. Dorsal fold subtriangular. Median furrow in both valves. Fine, concentric growth lines present anterior to umbos.

Interior. Teeth stout, elongate in cross-section. Delthyrial cavity yoked. Sockets broad and shallow; vascula media extend from the umbo, outer hinge plates discrete, divergent. Adductor scars flabellate and slightly impressed. Spiralia dorsomedially directed and consist, in large specimens, of eight to nine whorls.

Comparison. This species is smaller, more globose, and more pointed posteriorly than *A. prunum*. It resembles *A. vagranica* (Khodalevich, 1939, Pl. 24, fig. 1), but is more pointed and globose. *Atrypella carinata* (Johnson and Reso, 1964, Pl. 20, figs. 18–26) is larger, more lenticular, and less globose than *A. phoca*.

Atrypella scheii (Holtedahl 1914)

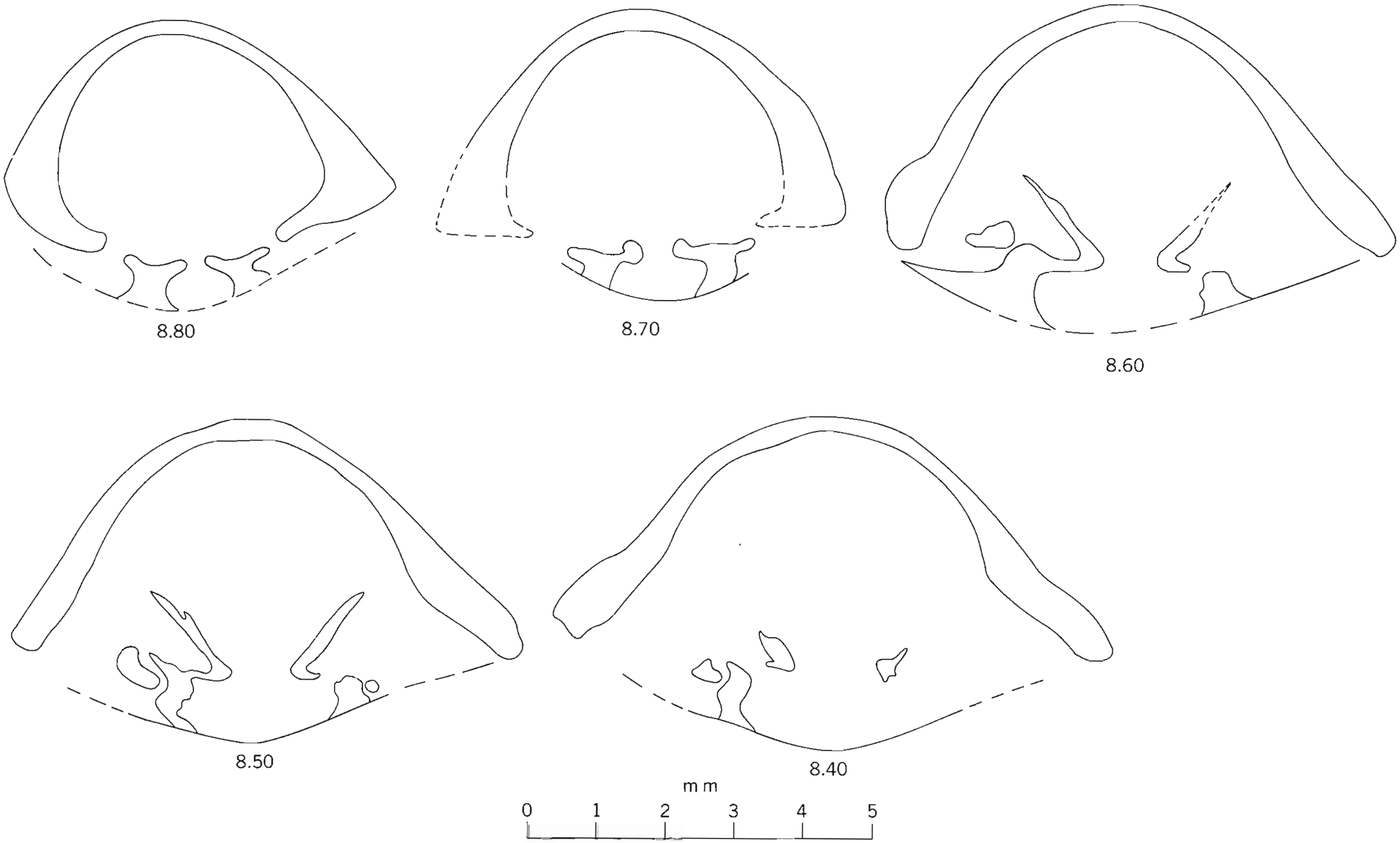
Lissatrypa scheii Holtedahl, 1914, Pl. 8, figs. 10, 12.

Discussion. In his description of *A. scheii*, Holtedahl (1914) differentiated it from *A. phoca*, but also mentioned the variations in outline and convexity. Because few specimens were figured, workers are not certain as to the limits of this variability. However, I feel it advisable to illustrate probable variations as *A. scheii* rather than erect new species. In addition, I have examined the type specimens of *A. scheii* and found that those specimens illustrated in figures 9 and 11 of Plate 7 (Holtedahl, 1914) are not *Atrypella*. They possess dental laminae and are similar to *Protathyris infantile* Kozlowski. In this study, several forms of *A. scheii* have been distinguished and arbitrarily designated as forms A, B, and C. However, gradation exists between these forms, and in some collections it is impossible to distinguish between smaller specimens and to assign them to the various forms.

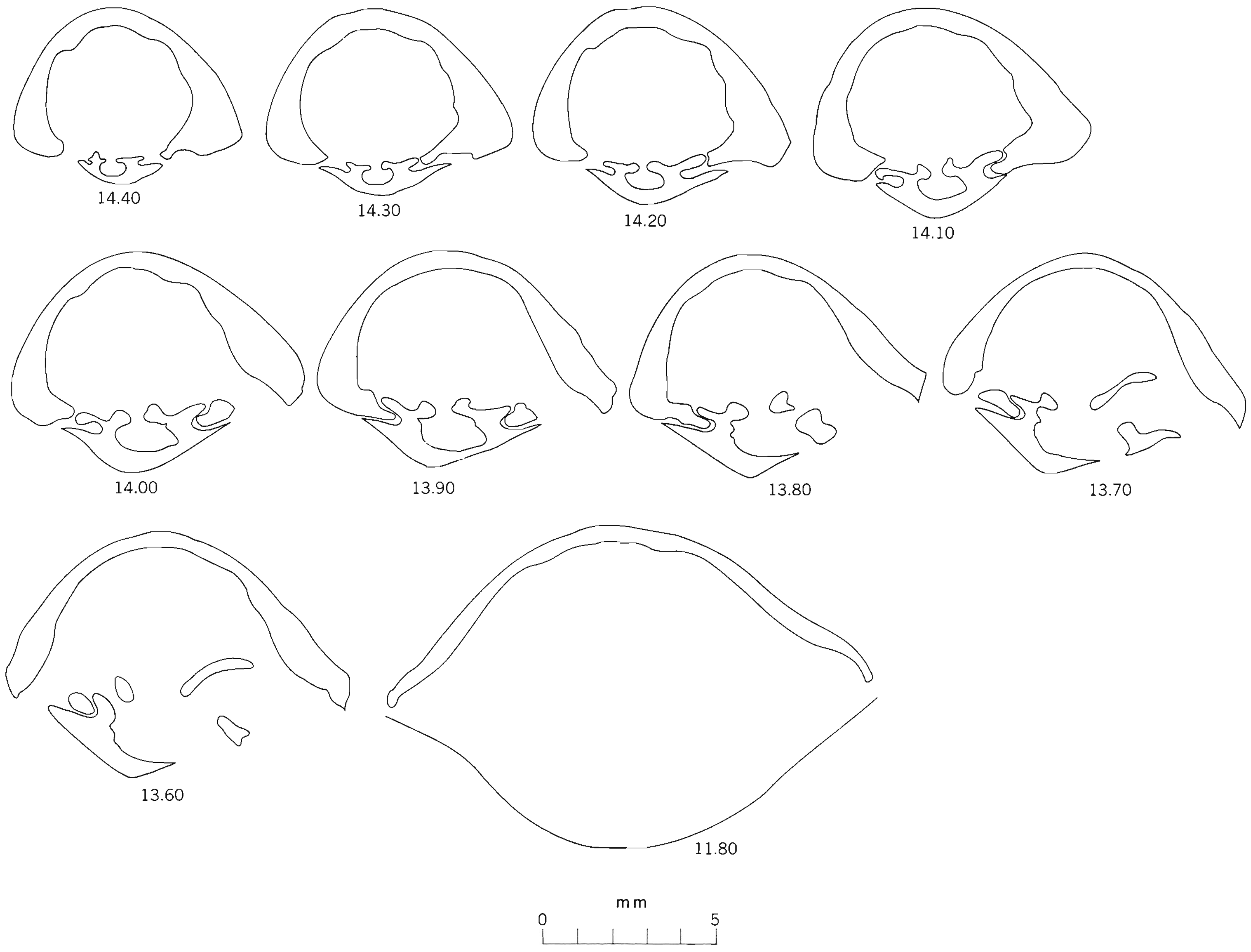
Atrypella scheii (Holtedahl 1914) form A

Plate 6, figures 13–17; Textfigure 14

Material. Figured specimens GSC 34043, 34044, and 34058 from GSC locality C-11954; additional specimens from GSC localities C-11955, C-11960, C-11961, and C-11962; Devon Island.



TEXTFIGURE 14. Drawings of acetate peels from serial sections of *Atrypella scheii* (Holtedahl) form A (x10.45). Highest numbers (mm) are closest to posterior end of specimen. GSC 34058, GSC locality C-11954, Devon Island.



TEXTFIGURE 15. Drawings of acetate peels from serial sections of *Atrypella scheii* (Holtedahl) form B (x6). Highest numbers (mm) are closest to posterior end of specimen. GSC 34059, GSC locality C-11954, Devon Island.

Discussion. This form has a restricted range within the sections measured, but ranges are not consistent between sections. These shells are normally wider than long and moderately biconvex.

Exterior. Outline subtriangular to subcircular; slightly dorsibiconvex in lateral profile. Interarea lacking; ventral beak incurved. Large specimens lack foramen; delthyrium not observed. Hinge line broad and straight. Cardinal angles obtuse; maximum width occurs posterior to midlength. Ventral sulcus and dorsal fold almost nonexistent; in some specimens, a slight deflection in the commissure indicates their presence. Faint, concentric growth lines restricted to anterior.

Interior. Teeth moderately stout, elongate in cross-section. Delthyrial cavity yoked. Vascula media extend anteriorly. Sockets moderately deep and broad. Crural bases connected to socket ridges by discrete, divergent hinge plates. Primary lamellae connected to crural bases. Low myophragm confined to umbo. Spiralia dorsomedially directed and consist, in large specimens, of eight to nine whorls.

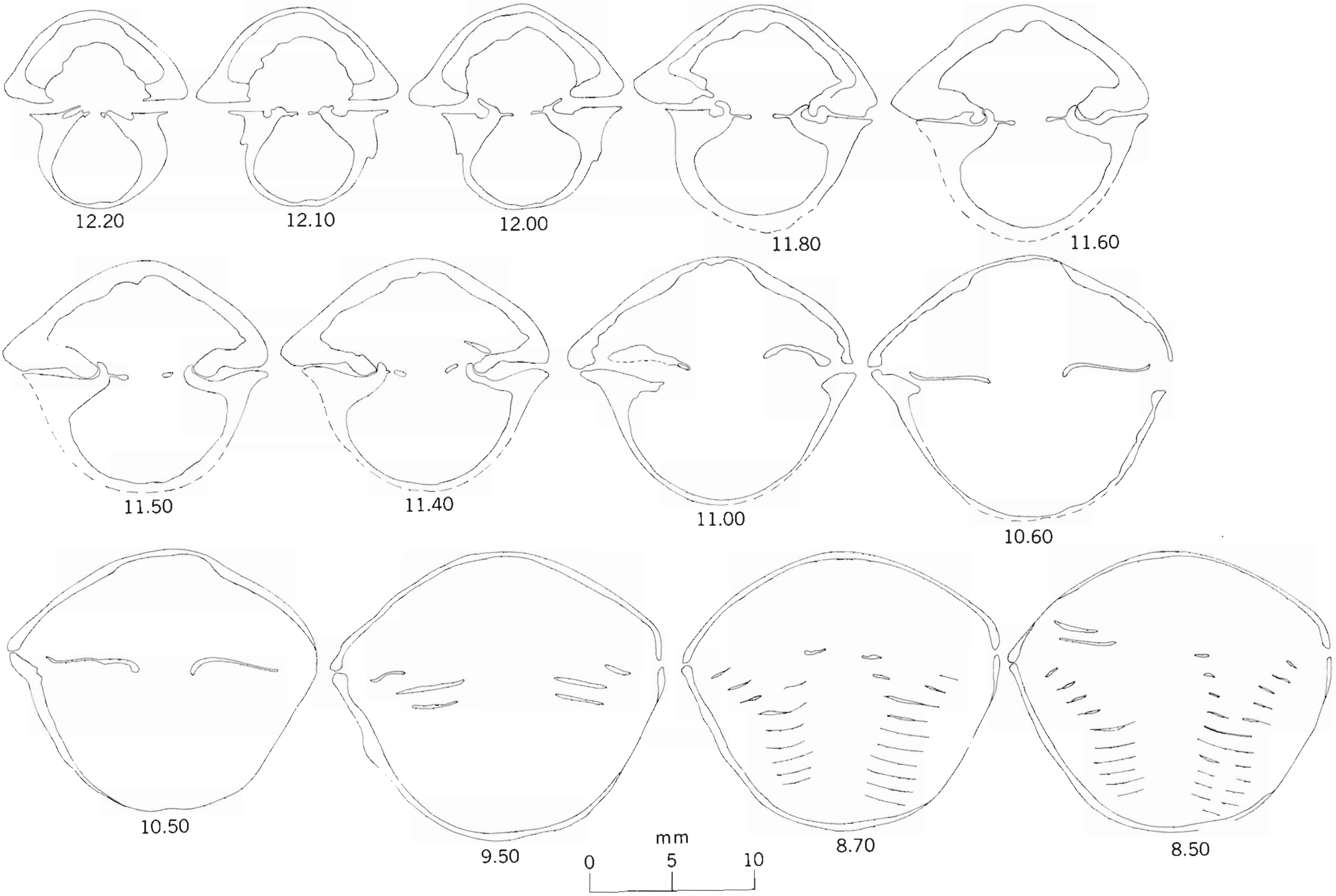
Comparison. This form is much more triangular and less convex than *A. scheii* form B or C (this paper). It is similar to *A. scheii* (Holtedahl) Kirk and Amsden (1952, Pl. 7, figs. 17–22), but is more triangular in outline and less convex. It is similar to a specimen of *A. kuschvensis* (Khodalevich, 1939, Pl. 23, fig. 3a).

Atrypella scheii (Holtedahl 1914) form B
Plate 6, figures 18–22; Textfigure 15

Material. Figured specimens GSC 34045, 34046, and 34059 from GSC locality C-11954; additional specimens from GSC localities C-11951, C-11952, C-11953, C-11955, C-11956, C-11957, C-11958, C-11959, C-11960, C-11962; Devon Island.

Discussion. This form has a longer stratigraphic range within the measured sections than form A or C. However, between sections, ranges are not consistent. Form B is not present in all collections within its observed range.

Exterior. Outline lenticular and subrectangular, dorsibiconvex in lateral profile. Ventral beak incurved over dorsal



TEXTFIGURE 16. Drawings of acetate peels from serial sections of *Atrypella scheii* (Holtedahl) form C (x2.5). Highest numbers (mm) are closest to posterior end of specimen. GSC 34060, GSC locality C-11961, Devon Island.

umbo. Interarea lacking. Large specimens lack a foramen; delthyrium not observed. Hinge line slightly curved and moderately broad. Cardinal angles obtuse. Maximum width slightly posterior to midlength. Shallow ventral sulcus developed in anterior; dorsal fold low, broad. Ornament consists of faint, concentric growth lines anterior to the umbo.

Interior. Hinge teeth stout, elongate in cross-section. Delthyrial cavity yoked. Vascula media extend anteriorly. Sockets shallow and broad. Discrete hinge plates diverge anteriorly. Low myophragm confined to the umbo. Faintly impressed adductor scars are flabellate.

Comparison. This form differs from either form A or C by its elongate, subrectangular outline. It resembles *A. linguata* (Nikiforova, 1937, Pl. 9, fig. 1), but is more elongate with a broader hinge line.

Atrypella scheii (Holtedahl 1914) form C

Plate 6, figures 23, 24; Plate 7, figures 1–4; Textfigure 16

Material. Figured specimens GSC 34047, 34048, and 34060 from GSC locality C-11961; additional specimens from GSC localities C-11952, C-11953, C-11958, C-11959, C-11960, C-11962, C-11963, and C-11964; Devon Island.

Discussion. This form has a limited, inconsistent range within both measured sections. It is very similar to *A. scheii* (Holtedahl, 1914, Pl. 7, fig. 12). It also is very similar to *A. scheii* forma typica (Nikiforova, 1970, Pl. 4, fig. 7).

Exterior. Outline subrectangular to nearly square, dorsibiconvex in lateral profile. Ventral beak incurved and impressed over dorsal umbo. Large specimens lack foramen; delthyrium not observed. Cardinal angles obtuse. Interarea lacking. Hinge line broad and slightly curved; maximum width occurs posterior to midlength. Shallow ventral sulcus in anterior region. Subrectangular in cross-section. Dorsal fold poorly developed in anterior. Concentric growth lines developed anterior to umbos.

Interior. Hinge teeth stout, elongate in cross-section. Delthyrial cavity yoked. Vascula media extend anteriorly. Sockets moderately deep and broad. Discrete, outer hinge plates divergent. Flabellate adductor scars slightly impressed. Low myophragm confined to the umbo. Spiralia dorsomedially directed and consist, in large specimens, of twelve whorls.

Comparison. This form is more square in outline and more dorsibiconvex than form A or B. It resembles *A. camelina* (Buch) (Khodalevich, 1939, Pl. 22, figs. 1–5) but its pedicle valve is not as inflated. It is not as biconvex or as pointed posteriorly as *A. phoca.*

Genus **Cryptatrypa** Siehl 1962

Type species. *Terebratula philomela* Barrande 1947.

Cryptatrypa? sp.

Material. Specimens from GSC locality C-11951; Devon Island.

Discussion. A few loose specimens that were weathered free from the matrix were collected. Consequently, they are of little biostratigraphic value. Specimens of this genus were small and poorly preserved.

Description. Outline lenticular to suboval; nearly biconvex in lateral profile. Hinge line curved, short; interarea lacking. Maximum width at midlength. Shallow ventral sulcus developed in anterior. Dorsal fold represented by a deflection in the commissure. Thin dental lamellae confined to umbo.

Suborder *ATHYRIDOIDEA*

Subfamily PROTATHYRIDINAE Boucot, Johnson, and Staton 1964

Genus **Protathyris** Kozlowski 1929

Type species. *Protathyris praecursor* Kozlowski 1929.

Protathyris aff. *P. infantile* Kozlowski 1929

Plate 7, figures 15–19; Textfigure 17

aff. *Protathyris infantile* Kozlowski, 1929, p. 230, Pl. XI, fig. 47.

Material. Figured specimens GSC 34051, 34052, and 34061 from GSC locality C-11951; additional specimens from GSC localities C-11952, C-11953, C-11955, C-11956, C-11957, C-11959, C-11960, C-11962; Devon Island.

Discussion. This species occurs in moderate abundance in both sections, particularly in the central levels. It is similar to *P. infantile* Kozlowski, but is larger and has a more circular outline. *Protathyris infantile* occurs in the Ludlow of Podolia (Kozlowski, 1929).

Exterior. Outline subcircular to subpentagonal; slightly dorsibiconvex in lateral profile. Hinge line short, curved; interarea small. Ventral beak slightly incurved. Cardinal angles obtuse; maximum width occurs at midlength. Ventral sulcus and dorsal fold poorly developed in mature specimens.

Interior. Hinge teeth thin, pointed, elongate in cross-section. Thin dental lamellae confined to umbo. Delthyrium moderately high, triangular, open, and bounded by two deltidial plates. Sockets moderately deep and broad. Hinge plates divided by small fissure, uniting anteriorly, forming a dorsally convex cardinal plate. Low myophragm confined to umbo. Spiralia directed laterally.

Comparison. This species differs from *P. didyma* Kozlowski, 1929, *non* Dalman in that it is less convex, smaller, and broader. It lacks the prominent growth lines of *P. praecursor.*

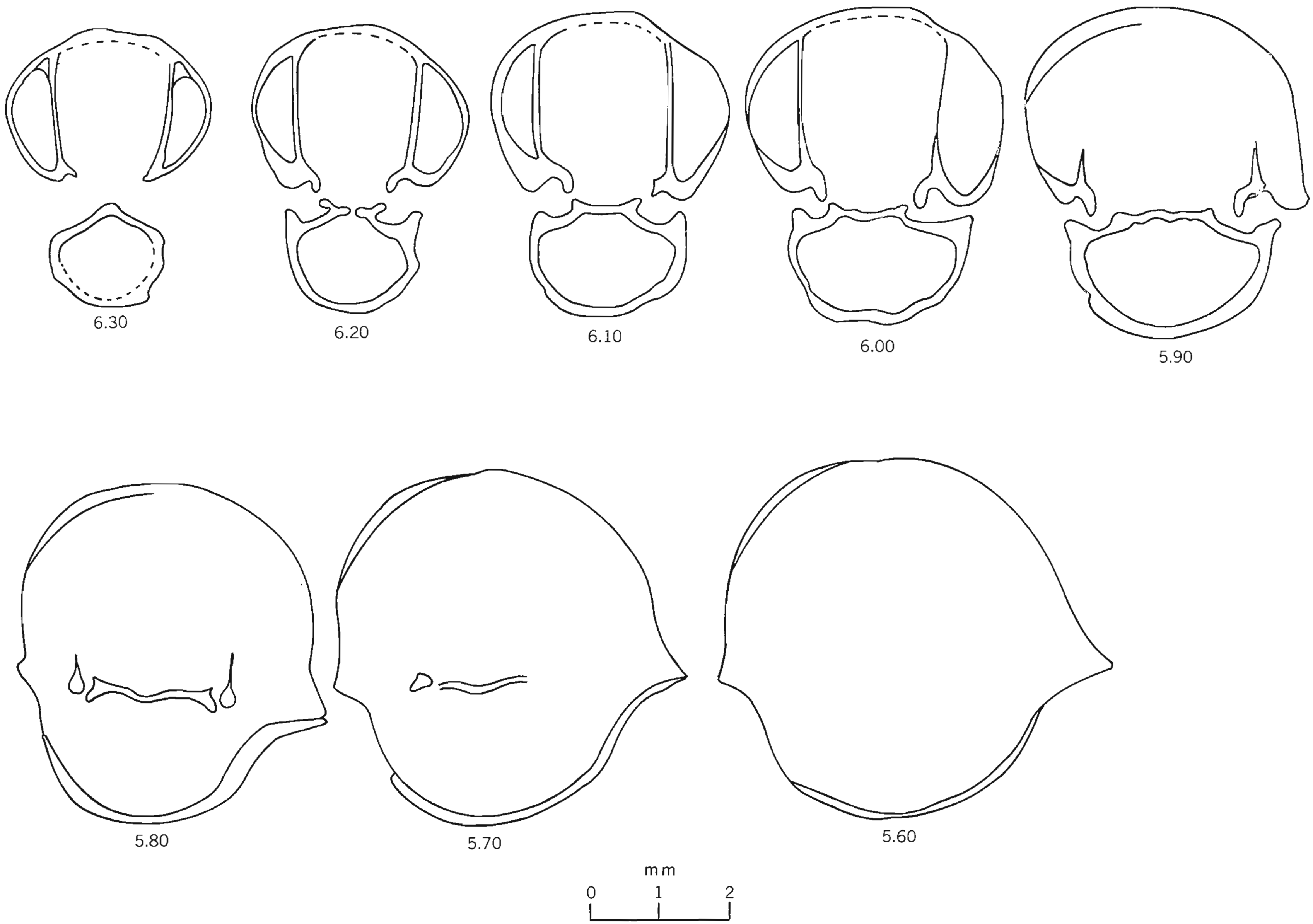
Protathyris didyma Kozlowski 1929

Plate 7, figures 10–14; Textfigure 18

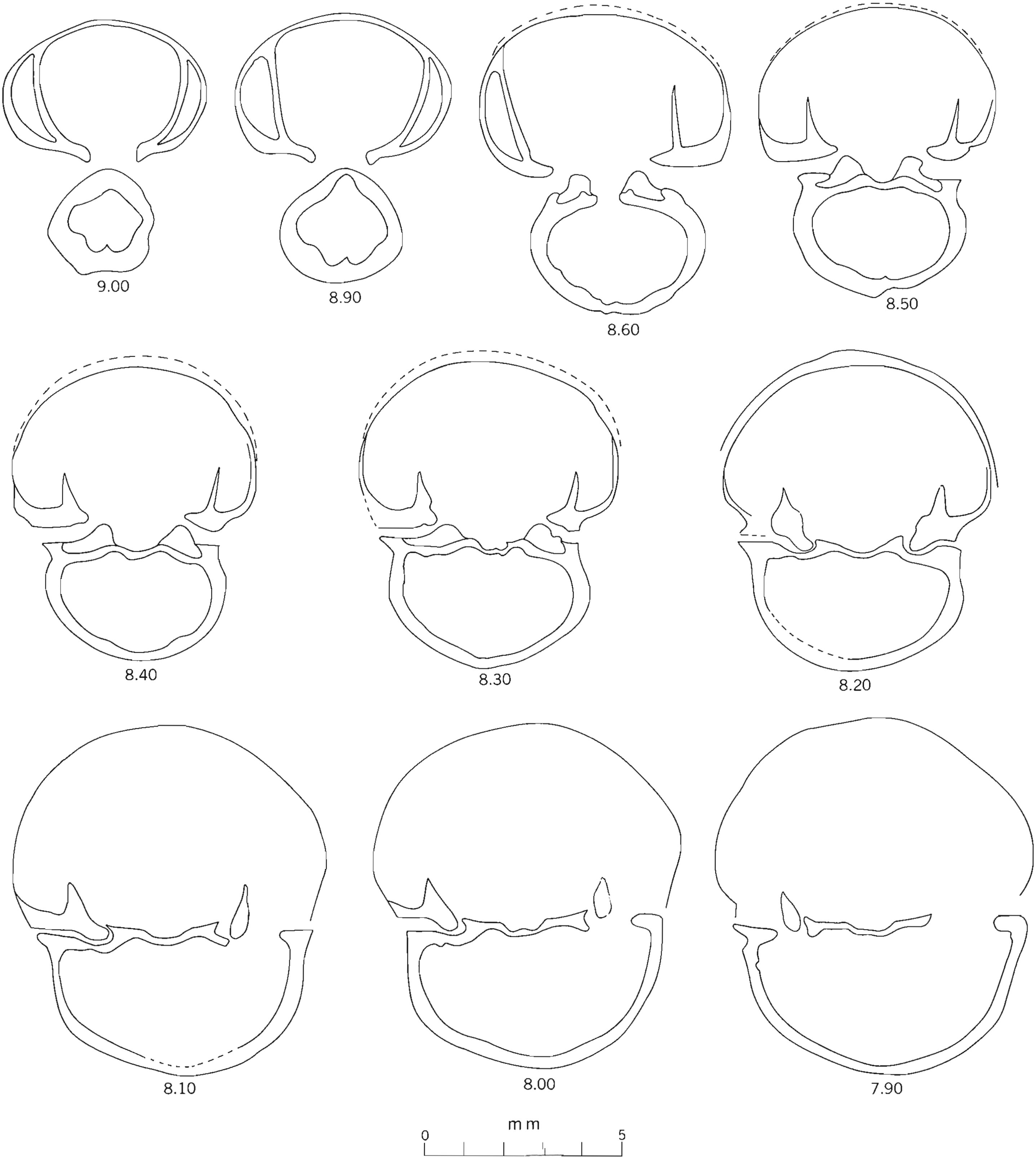
Protathyris didyma Kozlowski, 1929, p. 227, Pl. XII, figs. 28–40.
non *Protathyris didyma* (Dalman), 1828, Pl. 6, fig. 7.

Material. Figured specimens GSC 34050 and 34062 from GSC locality C-11952; additional specimens from GSC localities C-11951, C-11953, C-11956, C-11959, C-11960, C-11961, C-11962; Devon Island.

Discussion. This species is not to be confused with *P. didyma* (Dalman, 1828). The latter possesses a pedicle support and



TEXTFIGURE 17. Drawings of acetate peels from serial sections of *Protathyris* aff. *P. infantile* Kozlowski (x12). Highest numbers (mm) are closest to posterior end of specimen. GSC 34061, GSC locality C-11951, Devon Island.



TEXTFIGURE 18. Drawings of acetate peels from serial sections of *Protathyris didyma* Kozlowski (x7.2). Highest numbers (mm) are closest to posterior end of specimen. GSC 34062, GSC locality C-11952, Devon Island.

has been separated from *Protathyris* with the creation of *Didymothyris didyma* Rubel and Modzalevskaya (1967, Pl. 1, figs. 1–13).

Exterior. Outline elongate, subpentagonal, suboval; biconvex in lateral profile. Hinge line short, curved; interarea small. Ventral beak raised, gently incurved. Cardinal angles acute. Maximum width anterior to midlength. Ventral median furrow merges with the sulcus in some specimens. Ventral sulcus and dorsal fold variably developed anteriorly. Faint, concentric growth lines developed anterior to umbos.

Interior. Hinge teeth stout, subellipsoidal in cross-section. Well-developed dental lamellae restricted to umbo. Moderately high, triangular, open delthyrium bounded by two deltidial plates. Muscle scars not impressed. Sockets moderately deep and broad. Hinge plates divided apically by small fissure, uniting anteriorly, forming convex cardinal plate. Low myophragm confined to umbo. Spiralia laterally directed.

Comparison. This species differs from *P. praecursor* by being larger, more convex and pointed in outline.

Order ***RHYCHONELLIDA***

Subfamily RHYNCHOTREMATINAE Schuchert 1913

Genus ***Ferganella*** Nikiforova 1937

Type species. *Ferganella turkestanica* Nikiforova 1937.

Ferganella cf. *F. turkestanica* Nikiforova 1937

Plate 7, figures 20–25; Textfigure 19

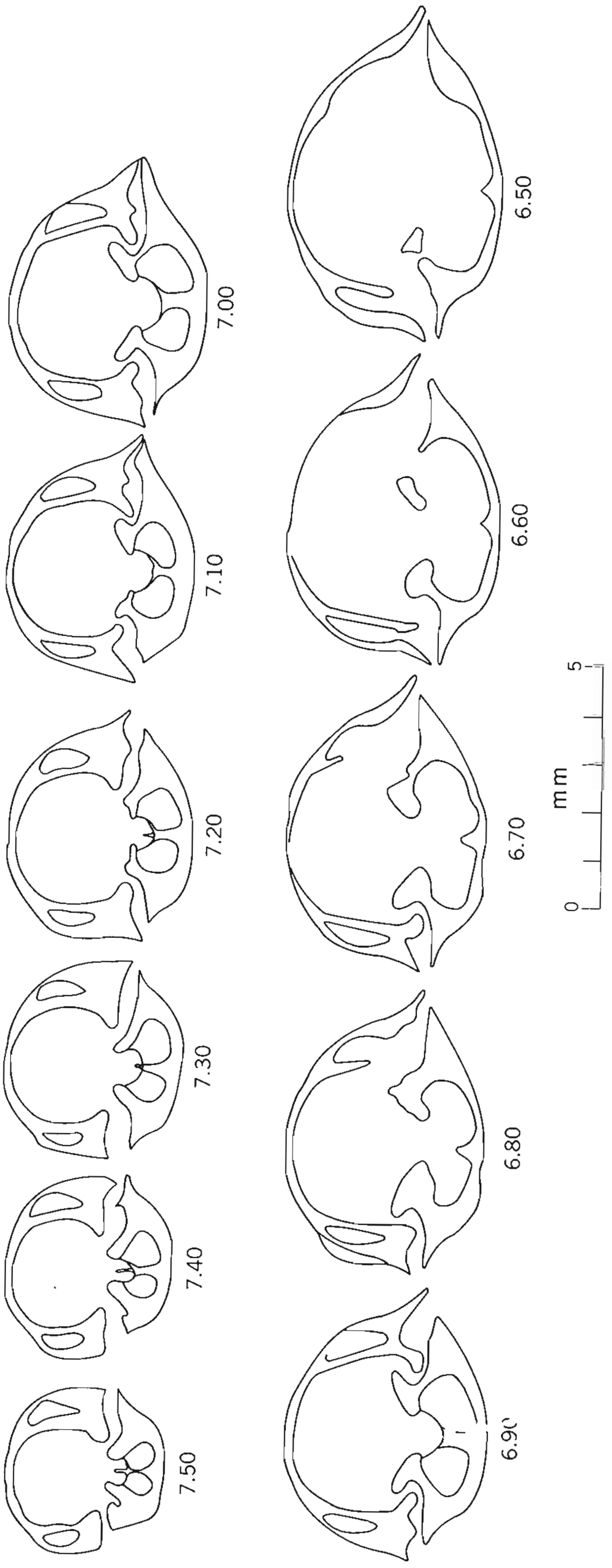
cf. *Ferganella turkestanica* Nikiforova, 1937, p. 39, Pl. VII, figs. 10–16.

Material. Figured specimens GSC 34053, 34054, and 34063 from GSC locality C-11952; additional specimens from GSC localities C-11955, C-11956, C-11957, C-11963, C-11964; Devon Island.

Discussion. This form is very similar to *F. turkestanica*, both internally and externally. However, illustrations of the types are not clear, nor do they illustrate the ventral muscle field. Until type material can be examined, the writer feels it advisable to assign specimens from Devon Island as *F.* cf. *F. turkestanica.*

Exterior. Outline subpentagonal to subtriangular; dorsibiconvex in lateral profile. Ventral beak suberect. Hinge line curved, short; interarea lacking. Cardinal angles obtuse; maximum width posterior to midlength. Ventral sulcus moderately developed, containing six costae. Dorsal fold low, broad, containing six costae. Costae cover entire shell surface, but weaker at umbos.

Interior. Hinge teeth stout. Well-developed dental lamellae confined to umbo. Adductor scars, paired, elongate, subelliptical in outline and confined to sulcus. Bounded by pair of anteriorly divergent diductor tracks. Sockets moderately deep and broad. Notothyrial cavity large, oval, supported by thick median septum. Cardinal process septaform.



TEXTFIGURE 19. Drawings of acetate peels from serial sections of *Ferganella* cf. *F. turkestanica* Nikiforova (x6.5). Highest numbers (mm) are closest to posterior end of specimen. GSC 34063, GSC locality C-11952, Devon Island.

Suborder *SPIRIFEROIDEA*

Family RETICULARIIDAE Waagen 1883

Genus ***Spirinella*** Johnston 1941

Type species. *Spirinella caecistriata* Johnston 1941.

Spirinella sp.
Plate 7, figures 5–9

Material. Figured specimen GSC 34049 from GSC locality C-11951; Devon Island.

Discussion. Few specimens were encountered, and at only one locality. This species is similar to *Spirifer modestus* Hall var. *striatissmus* Holtedahl (1914, Pl. 7, fig. 2).

TABLE 2. *Measurements of specimens. All measurements in mm.*

	Length	Width	Thickness
Atrypella prunum (Dalman)	36.0	26.5	26.0
	32.1	25.7	23.3
	32.4	27.3	21.7
	30.2	25.4	23.4
	33.0	25.3	20.8
Atrypella phoca (Salter)	22.5	18.6	20.1
	20.1	18.6	17.3
	19.1	16.8	15.3
	21.7	21.2	17.0
	21.3	19.7	18.2
Atrypella scheii (Holtedahl) form A	10.8	13.1	5.0
	14.8	16.0	8.7
	15.7	15.4	9.2
	16.3	16.8	8.6
	8.2	9.3	4.0
Atrypella scheii (Holtedahl) form B	20.4	17.3	12.5
	19.4	16.4	10.8
	18.1	15.0	9.6
	11.5	10.1	5.9
	7.8	7.2	3.6
Atrypella scheii (Holtedahl) form C	17.9	17.3	14.0
	18.7	18.3	16.7
	21.2	19.2	17.0
	19.1	17.5	16.4
	16.6	16.1	15.7
Protathyris didyma Kozlowski	14.1	12.1	10.7
	15.6	13.1	11.2
	15.5	12.8	11.7
	17.6	15.0	13.2
	16.1	14.6	12.0
Protathyris aff. *P. infantile* Kozlowski	16.0	15.0	9.8
	11.4	11.2	6.5
	8.8	9.1	5.5
	8.3	8.6	4.8
	9.7	9.4	5.9
Ferganella cf. *F. turkestanica* Nikiforova	9.7	12.8	7.0
	9.6	11.5	5.5
	11.3	12.6	7.4
	10.0	11.5	6.2
	8.8	8.8	6.6
Howellella sp.	5.1	6.3	3.7
	5.8	7.1	4.7
	5.6	6.2	4.4
	6.1	7.2	4.6
	7.5	8.2	5.2

Description. Transversely elliptical; ventribiconvex in lateral profile. Hinge line straight and broad. Interarea low, broad, and triangular. Ventral beak raised and slightly incurved. Delthyrium triangular and appears to be open. Cardinal margins submegathyrid. Cardinal angles obtuse; maximum width at midlength. Anterior commissure weakly uniplicate. Ornamentation consists of fine radiating striae superposed on fine, concentric growth lines. Thin dental lamellae confined to umbo.

Family DELTHYRIDIDAE Phillips 1841

Subfamily DELTHYRIDINAE Phillips 1841

Genus ***Howellella*** Kozlowski 1946

Type species. *Terebratula crispus* Hisinger 1826.

Howellella sp.
Plate 7, figures 26–30

Material. Specimens GSC 34055 and 34056 from GSC locality C-11954; additional specimens from GSC localities C-11951, C-11952, C-11953, C-11955, C-11956, C-11957, C-11958, C-11959, C-11960, C-11961, C-11962, C-11963; Devon Island.

Discussion. This genus was encountered in nearly all collections examined. Numerous specimens were prepared as internal moulds, but none was serial sectioned. It is very similar to *Spirifer vanuxemi* Hall var. *prognostica* Schuchert (Holtedahl, 1914, Pl. 8, fig. 4).

Description. Outline transversely elliptical; ventribiconvex in lateral profile. Hinge line straight, wide. Ventral interarea apsacline. Ventral beak slightly curved. Delthyrium triangular and open. Cardinal angles obtuse; maximum width posterior to midlength. Anterior margins rounded. Ventral sulcus and dorsal fold well developed. Lateral plications few and decrease in height away from the sulcus. Well-developed dental lamellae confined to umbo.

Suborder *STROPHOMENOIDEA*

Family CHILIDIOPSIDAE Boucot 1959

Genus ***Iridistrophia*** Havlicek 1965

Type species. *Orthis umbella* Barrande 1848.

Iridistrophia ? sp.

Material. One articulated specimen from GSC locality C-11952; Devon Island. Numerous disarticulated specimens were found that probably also represent *Iridistrophia ?* sp.

Description. Outline suboval to semicircular. Ventral valve slightly concave, dorsal valve convex. Hinge line broad, straight. Ventral interarea low, broad, triangular. Delthyrium covered by a triangular, convex pseudodeltidium. Neither dorsal interarea nor chilidium apparent. Maximum width between hinge and midlength. Costellae radiate from the umbos and increase in number anteriorly by intercalation. Paired dental lamellae long and divergent.

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APPENDIX

Locality register and distribution of faunal constituents

GSC loc. C-11951, Section 5, E504250, N8475000, 775 feet below top of Douro Formation (C-11950 from talus at same horizon)

Sample	Number of specimens	A*	D*	A/D	Percentage of total fauna
Sample C-11951a					
Atrypella	11	9	2	4.5	8
Howellella	20	7	13	0.5	14
Protathyris	96	72	24	3.0	67
indet. stroph.	4	0	4		3
ostracodes	10				8
indeterminate	40				
Total 181 specimens					
Sample C-11951b					
Atrypella	10	8	2	4.0	7
Howellella	2	1	1	1.0	1
Protathyris	115	110	5	22.0	85
ostracodes	2				1
indet. auloporid	2				1
indeterminate	35				
Total 166 specimens					
Sample C-11951c					
Atrypella	10	9	1	9.0	4
Howellella	27	17	10	1.7	10
Protathyris	199	195	4	48.8	75
indet. stroph.	3				1
ostracodes	26				
indeterminate	50				
Total 315 specimens					

GSC loc. C-11952, Section 5, 505 feet below top of Douro Formation

Sample	Number of specimens	A*	D*	A/D	Percentage of total fauna
Sample C-11952b					
Atrypella	730	567	163	3.5	73
Howellella	17	1	16	0.06	1.6
Protathyris	181	160	21	7.6	18
Iridistrophia ?	1	1	0		0.1
indet. stroph.	39	0	39		4
Ferganella	32	20	12	1.7	3
gastropod	1				
coral	1				
crinoid	1				
indeterminate	127				
Total 1,130 specimens					
Sample C-11952c					
Atrypella	215	24	191	0.12	76
Howellella	31	1	30	0.03	11
Protathyris	23	6	17	0.35	8
gastropods	13				5
indeterminate	58				
Total 340 specimens					

GSC loc. C-11953, Section 5, 405 feet below top of Douro Formation

Sample	Number of specimens	A*	D*	A/D	Percentage of total fauna
Sample C-11953a					
Atrypella	603	557	46	12.1	87
Howellella	20	2	18	0.1	3
Protathyris	48	39	9	4.6	7
ostracodes	21				3
indeterminate	132				
Total 824 specimens					
Sample C-11953b					
Atrypella	191	79	112	0.7	69
Howellella	40	0	40		14
Protathyris	8	3	5	0.6	4
ostracodes	37				13
indeterminate	56				
Total 332 specimens					
Sample C-11953c					
Atrypella	148	42	106	0.4	61
Howellella	76	2	74	0.3	31
Protathyris	3	0	3		1
ostracodes	16				6.5
gastropods	1				0.5
indeterminate	51				
Total 295 specimens					

GSC loc. C-11954, Section 5, 255 feet below top of Douro Formation

Sample	Number of specimens	A*	D*	A/D	Percentage of total fauna
Sample C-11954a					
Atrypella	49	21	28	0.75	44
Howellella	35	11	24	0.46	31.5
Protathyris	1	0	1		1
indet. stroph.	6	0	6		5.5
indet. brach.	8	0	8		7
ostracodes	2				2
indeterminate	19				
Total 120 specimens					
Sample C-11954b					
Atrypella	280	194	86	2.3	82
Howellella	48	32	15	2.2	14
Protathyris	0				
indet. stroph.	11	0	11		3
ostracodes	2				
indeterminate	45				
Total 386 specimens					

GSC loc. C-11955, Section 5, 210 feet below top of Douro Formation

Sample	Number of specimens	A*	D*	A/D	Percentage of total fauna
Atrypella	149	46	103	0.44	68
Howellella	30	2	28	0.07	14
Protathyris	16	9	7	1.3	7
Ferganella	1	1	1	1.0	0.5
indet. stroph.	17				7.5
ostracodes	5				2
indeterminate	38				
Total 256 specimens					

GSC loc. C-11956, Section 5, 155 feet below top of Douro Formation

Sample	Number of specimens	A*	D*	A/D	Percentage of total fauna
Atrypella	291	96	195	0.49	70
Howellella	20	0	20		5
Protathyris	37	13	24	0.54	9
Ferganella	7	4	3	1.3	2
ostracodes	55				11
trilobites	2				0.5
gastropods	4				1
indeterminate	180				
Total 596 specimens					

A*–Articulated
D*–Disarticulated

Sample	Number of specimens	A*	D*	A/D	Percentage of total fauna

GSC loc. C-11957, Section 5, 35 feet below top of Douro Formation

Sample C-11957a					
Atrypella	19	14	5	2.8	36
Howellella	13	0	13		24.5
Protathyris	0				
Ferganella	9	5	4	1.25	17
gypidulid	8	0	8		15
ostracodes	1				2
trilobites	2				4
gastropods	1				2
indeterminate	0				
Total 53 specimens					
Sample C-11957b					
Atrypella	97	56	41	1.4	36
Howellella	44	2	42	0.05	16
Protathyris	6	2	4	0.5	2
Ferganella	16	2	14	0.14	6
indet. stroph.	86	0	86		32
ostracodes	6				2
trilobites	12				4.5
indeterminate	57				

Total 324 specimens

GSC loc. C-11958, Section 3, E508350, N8467500, 307 feet below top of Douro Formation

Atrypella	141	64	77	0.83	83
Howellella	26	4	22	0.18	15
indet. stroph.	3	0	3		2
indeterminate	19				

Total 189 specimens

GSC loc. C-11959, Section 3, 300 feet below top of Douro Formation

Atrypella	40	5	35	0.14	44
Howellella	20	0	20		22
Protathyris	15	7	8	0.88	16.5
indet. stroph.	7	0	7		8
ostracodes	9				8.5
indeterminate	36				

Total 127 specimens

GSC loc. C-11960, Section 3, 298 feet below top of Douro Formation

Atrypella	65	32	33	0.97	76
Howellella	9	0	9		11
Protathyris	11	8	3	2.7	13
ostracodes	1				1
indeterminate	33				

Total 119 specimens

GSC loc. C-11961, Section 3, 269 feet below top of Douro Formation

Atrypella	41	21	20	1.0	93
Howellella	1	0	1		2
Protathyris	2	0	2		4
indeterminate	36				

Total 80 specimens

Sample	Number of specimens	A*	D*	A/D	Percentage of total fauna

GSC loc. C-11962, Section 3, 265 feet below top of Douro Formation

Atrypella	87	32	55	0.58	73
Howellella	20	6	14	0.43	17
Protathyris	10	4	6	0.67	9
ostracodes	2				1
indeterminate	60				

Total 179 specimens

GSC loc. C-11963, Section 3, 254 feet below top of Douro Formation

Atrypella	105	1	104	0.01	50
Howellella	19	0	19		9
Protathyris	8	0	8		5
Ferganella	1	0	1		0.5
indet. stroph.	79	0	79		37
indeterminate	170				

Total 382 specimens

GSC loc. C-11964, Section 3, 246 feet below top of Douro Formation

Atrypella	28	25	3	8.3	88
Ferganella?	4	0	4		12
indeterminate	9				

Total 41 specimens

GSC loc. C-11965, Section 3, 245 feet below top of Douro Formation

Atrypella	16	0	16		15
indet. stroph.	91	0	91		85
indeterminate	39				

Total 146 specimens

GSC loc. C-11966, Section 3, 131 feet below top of Douro Formation

Atrypella	41	25	16	1.6	37
Protathyris	18	17	1	17.0	17
gypidulid	33	0	33		31
indet. stroph.	6	0	6		6
ostracodes	8				8
indeterminate	61				

Total 167 specimens

GSC loc. C-11967, Section 3, 3 feet below top of Douro Formation

Atrypella	11	5	6	0.83	64
ostracodes	2				11
trilobites	2				11
orthocone cephalopod	1				6
indeterminate	14				

Total 30 specimens

GSC loc. C-33721, isolated outcrop in large creek, north of Kennedy Bay, eastern Prince of Wales Island; Read Bay Formation.

USNM loc. 12671, Cape Phillips, Cornwallis Island; Cape Phillips Formation.

A*–Articulated
D*–Disarticulated

PLATE 6

Atrypella prunum (Dalman) (Page 20)

Figures 1, 3, 5, 6.	Pedicle, posterior, anterior, and lateral views, USNM 211560; USNM loc. 12671, Cornwallis Island; x about 1.1.
Figures 2, 4.	Brachial, posterior views of internal mould, USNM 211561; same locality; x about 1.1.

Atrypella phoca (Salter) (Page 20)

Figures 7, 10–12.	Pedicle, anterior, posterior, lateral views, GSC 34041; GSC loc. C-33721, Prince of Wales Island; x2.
Figures 8, 9.	Brachial, posterior views of internal mould, GSC 34042; same locality; x2.

Atrypella scheii (Holtedahl) form A (Page 22)

Figures 13–15.	Pedicle, brachial, anterior views of internal mould, GSC 34043; GSC loc. C-11954, Devon Island; x3.
Figures 16, 17.	Posterior, lateral views, GSC 34044; same locality; x2.

Atrypella scheii (Holtedahl) form B (Page 25)

Figures 18, 19, 21.	Pedicle, brachial, posterior views of internal mould, GSC 34045; GSC loc. C-11954, Devon Island; x2.
Figures 20, 22.	Anterior, lateral views, GSC 34046; same locality; x2.

Atrypella scheii (Holtedahl) form C (Page 26)

Figures 23, 24.	Pedicle, brachial views of internal mould, GSC 34047; GSC loc. C-11961, Devon Island; x2.

PLATE 6


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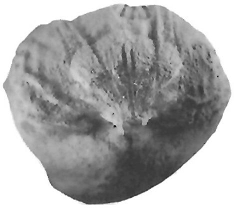
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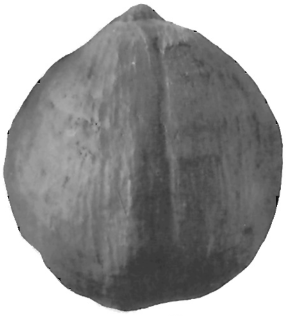
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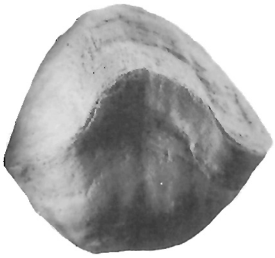
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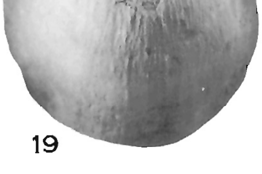
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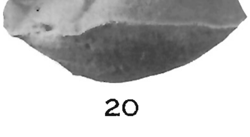
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PLATE 7

Atrypella scheii (Holtedahl) form C (Page 26)

Figure 1. Posterior view of interior mould, GSC 34047; GSC loc. C-11961, Devon Island; x2.

Figures 2–4. Posterior, anterior, lateral views, GSC 34048; same locality; x2.

Spirinella sp. (Page 30)

Figures 5–9. Pedicle, brachial, posterior, anterior, and lateral views, GSC 34049; GSC loc. C-11951, Devon Island; x4.

Protathyris didyma Kozlowski *non* Dalman (Page 26)

Figures 10–14. Pedicle, brachial, posterior, anterior, lateral views (x2) of internal mould, GSC 34050; GSC loc. C-11952, Devon Island.

Protathyris aff. *P. infantile* Kozlowski (Page 26)

Figures 15–17. Pedicle, brachial, posterior views of internal mould, GSC 34051; GSC loc. C-11951, Devon Island; x2.

Figures 18, 19. Anterior, lateral views, GSC 34052; same locality; x2.

Ferganella cf. *F. turkestancia* Nikiforova (Page 29)

Figures 20, 21, 23, 24. Pedicle, brachial, posterior, lateral views of internal mould, GSC 34053; GSC loc. C-11952, Devon Island; x3.

Figures 22, 25. Brachial, anterior view, GSC 34054; same locality; x3.

Howellella sp. (Page 30)

Figures 26, 28–30. Pedicle, posterior, anterior, lateral views, GSC 34055; GSC loc. C-11954, Devon Island; x4.

Figure 27. Pedicle view of internal mould, GSC 34056; same locality; x4.

Plate 7


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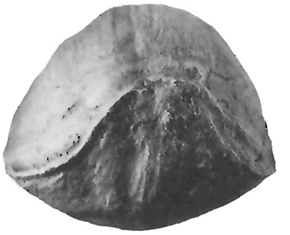
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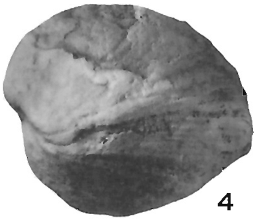
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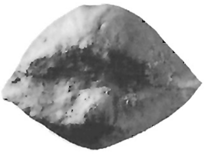
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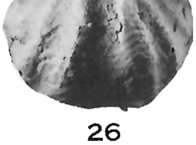
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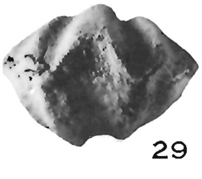
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A SYNRHABDOSOME OF *MONOGRAPTUS FANICUS* KOREN FROM THE LOWER DEVONIAN OF DEVON ISLAND, DISTRICT OF FRANKLIN

by D. E. Jackson[1], J. Wm. Kerr and D.W. Morrow

Abstract

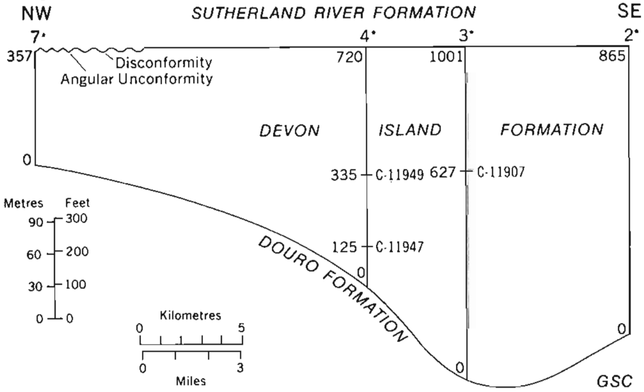
Monograptus fanicus Koren, of Early Devonian age, is identified for the first time in North America. It occurs as a synrhabdosome associated with single rhabdosomes in the Devon Island Formation. This is the first report of a synrhabdosome in the genus *Monograptus*.

Résumé

Monograptus fanicus Koren, d'âge Devonien inférieur, fut reconnu pour la première fois en Amérique du Nord. Sa découverte a eu lieu dans la formation Devon Island, et il se présente sous la forme d'un synrhabdosome associé à des rhabdosomes simples. C'est la première fois qu'un synrhabdosome appartenant au genre *Monograptus* est signalé.

Introduction

This paper contains the first description of a *Monograptus* synrhabdosome. The material of *M. fanicus* Koren from GSC locality C-11949 was collected from a stratigraphic section at Sutherland River (Textfig. 1, loc. 1; Textfig. 4, sec. 4; Textfig. 20), 210 feet (64 m) above an occurrence (GSC loc. C-11947) of *Monograptus* cf. *M. transgrediens* Perner identified by R. Thorsteinsson and correlated as late Pridolian (*M. transgrediens* Zone). An adjacent stratigraphic section (3 of Textfigs. 4 and 20) contains *Warburgella rugulosa canadensis* Ormiston at a horizon (GSC loc. C-11907; Textfig. 20) similar to that yielding *M. fanicus*. The trilobite was identified by A.W. Norris and dated as Gedinnian. According to Koren (1974), the Russian material of *M. fanicus* is dated as early Pragian (Siegennian).



TEXTFIGURE 20. Schematic cross-section of the Devon Island Formation, Sutherland River area, Devon Island. Locations of stratigraphic sections shown in Textfigure 4. Footages above base of Devon Island Formation of GSC sample localities C-11979, C-11947 and C-11907 are on the left side of each section. Numbers with asterisk refer to stratigraphic sections described by Morrow (1973) and by Morrow and Kerr (in press).

Synrhabdosomal associations are exceptionally rare and hitherto have been noted in only four Ordovician biserial genera, namely, *Climacograptus*, *Glyptograptus*, *Lasiograptus*, and *Orthograptus*. In all described cases, compound associations are found alongside single rhabdosomes. The precise significance of such synrhabdosomes is unknown. We would agree with Kozlowski (1949) who thought that in biserial genera they represented unusual reproductive associations. However, whereas synrhabdosomes of biserial graptolites may have been produced by asexual budding of the siculae, those in *Monograptus fanicus* are quite different in that the rhabdosomes are held together by slender threads connecting several virgulae.

Acknowledgments

The writers gratefully acknowledge help provided by Hermann Jaeger, Humboldt Universität, Berlin, concerning the diagnosis of *Monograptus fanicus* in advance of its publication by T.N. Koren.

Systematic Paleontology

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

Order ***GRAPTOLOIDEA*** Lapworth 1875

Family MONOGRAPTIDEA Lapworth 1873

Genus ***Monograptus*** Geinitz 1852

Monograptus fanicus Koren 1974

Textfigures 21, 22

Monograptus fanicus Koren, 1974, p. 251, 254, 256, Pl. 26, figs. 1–7, Textfig. 2, 3/8–3/15; nomen nudum.

Monograptus fanicus Koren, Koren 1975, p. 9–12, Pl. 2, figs. 4–8, Pl. 3, figs. 1–3, Pl. 4, figs. 3–8, Pl. 8, figs. 6–21.

Material. One synrhabdosome (GSC hypotype 34160) and more than twenty single flattened rhabdosomes (including

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[1] The Open University, Bletchley, England.

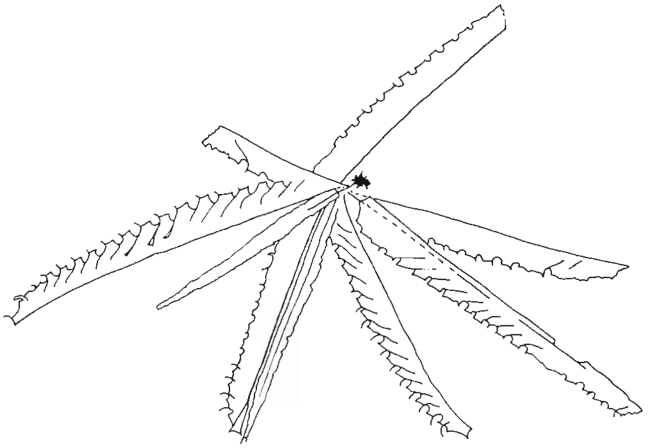
GSC hypotype 34161) preserved in a bituminous calcilutite are available for study from GSC locality C-11949, 335 feet (102 m) above the base of the Devon Island Formation and 385 feet (117 m) below its top at Sutherland River, Devon Island (Textfig. 1, loc. 1; Textfigs. 4 and 20, sec. 4); collected by D.W. Morrow, 1971.

Description. Synrhabdosome stellate, 25 mm in diameter, comprising an association of nine rhabdosomes in which six are seen to be attached to a knot of chitinous threads; no central "float" seen; rhabdosomes range in length from 11 to 17 mm and probably are fully grown. Associated rhabdosomes attain slightly larger sizes and are up to 25 mm long and essentially straight except for a slight dorsal curvature between sicular aperture and th^2. Sicula 1.6 to 1.9 mm long and 0.6 mm wide across trumpet-shaped aperture, apex of prosicula about level with aperture of th^2. Rhabdosome widens from 0.85–0.9 mm across aperture of th^1 (1.0 mm inclusive of hood) to 1.1–1.3 mm across th^5 (1.4 mm inclusive of hood) to 1.7 mm at th^{10}. A maximum width of 1.8 mm was measured on a distal fragment.

Thecae biform, first three of four thecae have large apertural hoods and free ventral walls inclined as much as 30 degrees; beyond th^7, free ventral walls are concave and parallel to the dorsal edge of rhabdosome and hoods are more like genicular flanges. Interthecal septa at proximal end inclined at 45 degrees to axis of sicula; distally straight, inclined at 25 to 35 degrees except at their dorsal extremities where they turn sharply toward the common canal. Seven thecae in first 5 mm and 6 per 5 mm distally.

Remarks. Koren (1974) has described how *M. fanicus* evolves from *M. aequabilis* (Přibyl) and that the two species have several characteristics in common. The features which this Canadian material exhibits that are diagnostic of *M. fanicus* are the flared sicular aperture, the dorsal curvature of the proximal end and the large hoods of about equal size on the first few thecae (*see* Textfig. 22).

Age and occurrence. According to Koren's (1974) study of the *M. aequabilis* – *M. fanicus* lineage in the Zeravsham-Gissar Mountains, there the local range zone of *M. fanicus* is early Pragian (Early Devonian). This would be compatible with the occurrence of the species on Devon Island in beds 210 feet (64 m) above an occurrence of *Monograptus* cf. *M. transgrediens* Perner (Textfig. 20).



TEXTFIGURE 21. *Monograptus fanicus* Koren, synrhabdosome (GSC hypotype 34160), Devon Island Formation, GSC locality C-11949, Sutherland River, Devon Island (x1.28).

TEXTFIGURE 22
Monograptus fanicus Koren, normal rhabdosome (GSC hypotype 34161) from same bedding plane as GSC 34160 (x3.5).

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SOME LOWER JURASSIC TRIGONIID BIVALVES FROM SOUTHWESTERN BRITISH COLUMBIA

by T.P. Poulton

Abstract

Psilotrigonia canadensis n. sp., *Trigonia* sp., *Vaugonia jeletzkyi* n. sp., and *V. vancouverensis* n. sp. are described from probable Pliensbachian beds of western Vancouver Island, and *V. coatesi* n. sp. and *V.* cf. *V. coatesi* n. sp. from probable Toarcian beds of Manning Provincial Park and Vancouver Island, respectively. *Psilotrigonia canadensis* n. sp. and *P. beesleyana* (Lycett) are differentiated from other '*Psilotrigonia*' spp. and are shown to have a restricted (Lower Pliensbachian to Middle Bajocian) biostratigraphic range. Species of *Vaugonia* appear to have considerable biostratigraphic potential in western Canada and United States.

Résumé

Psilotrigonia canadensis n. sp., *Trigonia* sp., *Vaugonia jeletzkyi* n. sp. and *V. vancouverensis* n. sp. ont été découverts dans des horizons d'âge Pliensbachian probable, de l'ouest de l'île de Vancouver. *V. coatesi* n. sp. et *V.* cf. *V. coatesi* n. sp. d'âge Toarcien probable ont été respectivement découverts dans le Manning Provincial Park et sur l'île de Vancouver. *Psilotrigonia canadensis* n. sp. et *P. beesleyana* (Lycett) sont dissociés des autres '*Psilotrigonia*' spp. et semblent avoir une distribution biostratigraphique très limitée (Pliensbachian inférieur à Bajocien moyen). Certaines espèces de *Vaugonia* semblent avoir une très grande valeur biostratigraphique dans l'ouest du Canada et les Etats-Unis.

Introduction

This report describes and illustrates some trigoniid bivalves from Lower Jurassic rocks of Vancouver Island (Textfig. 1, locs. 3, 5) and of Manning Provincial Park in the southern mainland of British Columbia (Textfig. 1, loc. 4). *Vaugonia vancouverensis* n. sp. occurs in western Vancouver Island. Closely similar forms in Upper Sinemurian or Pliensbachian rocks of Nevada and Pliensbachian rocks of Oregon and mainland British Columbia indicate a Pliensbachian age for the 'Pliensbachian–Toarcian Greywacke Unit' of the west coast of Vancouver Island (*see* Jeletzky, 1954, 1970). This unit also contains *Psilotrigonia canadensis* n. sp., *Trigonia* sp., and *V. jeletzkyi* n. sp. The biostratigraphic significance of *Psilotrigonia canadensis* n. sp. and species of *Trigonia* Bruguière sensu stricto is not well known, but the *P. beesleyana–canadensis* species group appears to be restricted to Lower Pliensbachian to Middle Bajocian rocks. *Vaugonia coatesi* n. sp. occurs in probable Toarcian rocks of Manning Park, and thus *V.* cf. *V. coatesi* n. sp. on Vancouver Island indicates a probable Toarcian age for its containing rocks.

Acknowledgments

J.A. Jeletzky (Geological Survey of Canada) provided samples and stratigraphic data, and gave encouragement and advice during the preparation of this paper. Published and unpublished reports by H. Frebold (Geological Survey of Canada) provided essential biostratigraphic information. R.W. Imlay (United States Geological Survey), N.J. Silberling (Stanford University), and J.M. Edmonds (Oxford University) arranged for the writer to study comparative material. Miss J. White (Geological Survey of Canada), E. Fernando and J. Keenan (Queen's University) assisted with the photography. R.W. Imlay, J.A. Jeletzky, W.W. Nassichuk, and B.S. Norford critically read the manuscript. Queen's University (particularly J.L. Usher and R.G. Greggs) provided advice, financial support, and working facilities.

Stratigraphy and Ages of Fossils

Pliensbachian and Toarcian fossils are known from only a few geographically separated localities in southwestern British Columbia, whose paleogeographic and stratigraphic relationships are poorly understood (*see* Frebold and Tipper, 1970). Regionally, the Lower Jurassic rocks commonly are dominated by volcanic and volcanoclastic material (apparently representing a modified continuation of widespread Triassic vulcanism) and overlie an unconformity indicating latest Triassic intrusion and tectonism (*see* Douglas *et al.*, 1970). The Lower Jurassic rocks of western Vancouver Island and those from Manning Park (although not directly volcanogenic) occur in thick, largely volcanic-related successions of pre-orogenic Mesozoic rocks characteristic of the western part of the Canadian Cordilleran orogenic belt.

The following brief discussions of stratigraphy and ages of rocks yielding trigoniid bivalves are supplemented by detailed locality data for individual collections (Appendix).

Manning Provincial Park

Vaugonia coatesi n. sp. occurs in rusty weathering, fine-grained clastic rocks of the Ladner Group in Manning Park, in the eastern Jurassic facies belt delineated by J.A. Coates (1974, and *in* Frebold *et al.*, 1969). A band of friable, deeply weathered coquina rubble occurs near the brow of the burnt-over ridge 2.5 miles (4 km) north-northeast of Allison Pass Summit and is thought to be approximately in situ. At the low elevation cited for GSC locality 69414 of Coates (*see* Appendix), the writer could find only loose boulders derived from the band of rubble near the brow of the hill, indicating the probable source of Coates' collection. The fossiliferous unit is stratigraphically below a steeply south-easterly dipping succession of tuffs, volcanic breccias, and volcanoclastic greywackes. This succession appears to be equivalent to lithologically similar Middle Bajocian rocks in the Lookout Section, along strike to the southeast, that were described by Frebold *et al.* (1969). Sedimentary rocks stratigraphically below the coquina unit apparently are unfossiliferous.

The rich and varied fauna associated with *V. coatesi* n. sp. includes fragmentary moulds of ammonites identified by H. Frebold as "*Grammoceras?* sp. indet." (unpubl. GSC internal rept.). Frebold suggested an age of "probably early part of late Toarcian." The fauna also includes *Weyla* sp., which is diagnostic of Lower Jurassic rocks (Frebold and Tipper, 1969), and poorly preserved belemnites which, in Canada, are unlikely to be older than Toarcian (Jeletzky, pers. com.). *Vaugonia coatesi* n. sp., therefore, is probably of Toarcian age, possible early late Toarcian. Locality 69415 previously was dated as Sinemurian on the presence of an arietitid ammonite (Coates, 1974, p. 22).

Western Vancouver Island

The Pliensbachian–Toarcian Greywacke Unit (Jeletzky, 1954, 1970) of the west coast of Vancouver Island (Textfig. 1, loc. 3) yielded *Vaugonia jeletzkyi* n. sp., *V. vancouverensis* n. sp., *Trigonia* sp., and *Psilotrigonia canadensis* n. sp. The stratigraphic distribution of trigoniids is based on Section 100 measured by J.A. Jeletzky in 1950 (*see* Textfig. 23). Jeletzky also supplied other information presented below. *Psilotrigonia canadensis* n. sp. occurs near the base of this succession in beds that elsewhere in the same area have yielded the Early Pliensbachian ammonite *Fanninoceras* McLearn. *Trigonia* sp. occurs in several beds higher in the unit, overlapping in range the uppermost trigoniid-bearing beds which yielded *V. vancouverensis* n. sp. and forms possibly synonymous with *V. jeletzkyi* n. sp. The last species is described from rocks occurring elsewhere in the same area that possibly may lie stratigraphically above Section 100. Poorly preserved ammonites are found associated with *V. vancouverensis* n. sp. near the exposed top of Section 100 and with *V. jeletzkyi*. The ammonites, designated *Grammoceras?* in Textfigure 23, are not identified positively (*see* discussion by Jeletzky, 1970, p. 15), but are of Late Pliensbachian or Toarcian age. A Pliensbachian age is favoured by the present writer based on the occurrence of *Vaugonia* sp. which, apparently, is conspecific with *V. vancouverensis* n. sp. in Upper Sinemurian beds of the Sunrise Formation of Nevada, and of very similar *Vaugonia* spp. in Pliensbachian rocks of Oregon and, possibly, in Upper Sinemurian rocks of central British Columbia.

Two specimens of *V.* cf. *V. vancouverensis* in collections of the late S. Wm. Muller of Stanford University bear a label indicating that they were collected from the "*Trigonia*" zone, that is, map-unit 8 of the section in New York Canyon, Gabbs Valley Range, Nevada (*see* Muller and Ferguson, 1939). They occur in medium-grained, grey to pink 'greywacke', and were collected "1½ miles south from the mouth [of the canyon presumably], along the western ridge . . ., west side of Flat Iron Knob" (Field no. 714-D). Associated *Eoderoceras* Spath indicates an Early Pliensbachian or possibly late Sinemurian age according to Muller and Ferguson (1939), and a Late Sinemurian age according to Imlay (1968).

The specimens of *Vaugonia* from the Pliensbachian of Oregon, and others from possible Upper Sinemurian beds of Hazelton map-area, central British Columbia (93M E1/2), are undescribed as yet. Those from Oregon occur in the Suplee Formation, in the abundantly fossiliferous upper part that has yielded ammonites of Late Pliensbachian age (*see* Imlay, 1968). The specimens from Hazelton map-area are associated with ammonites that were identified by Frebold as possibly *Leptechioceras*, possibly Late Sinemurian.

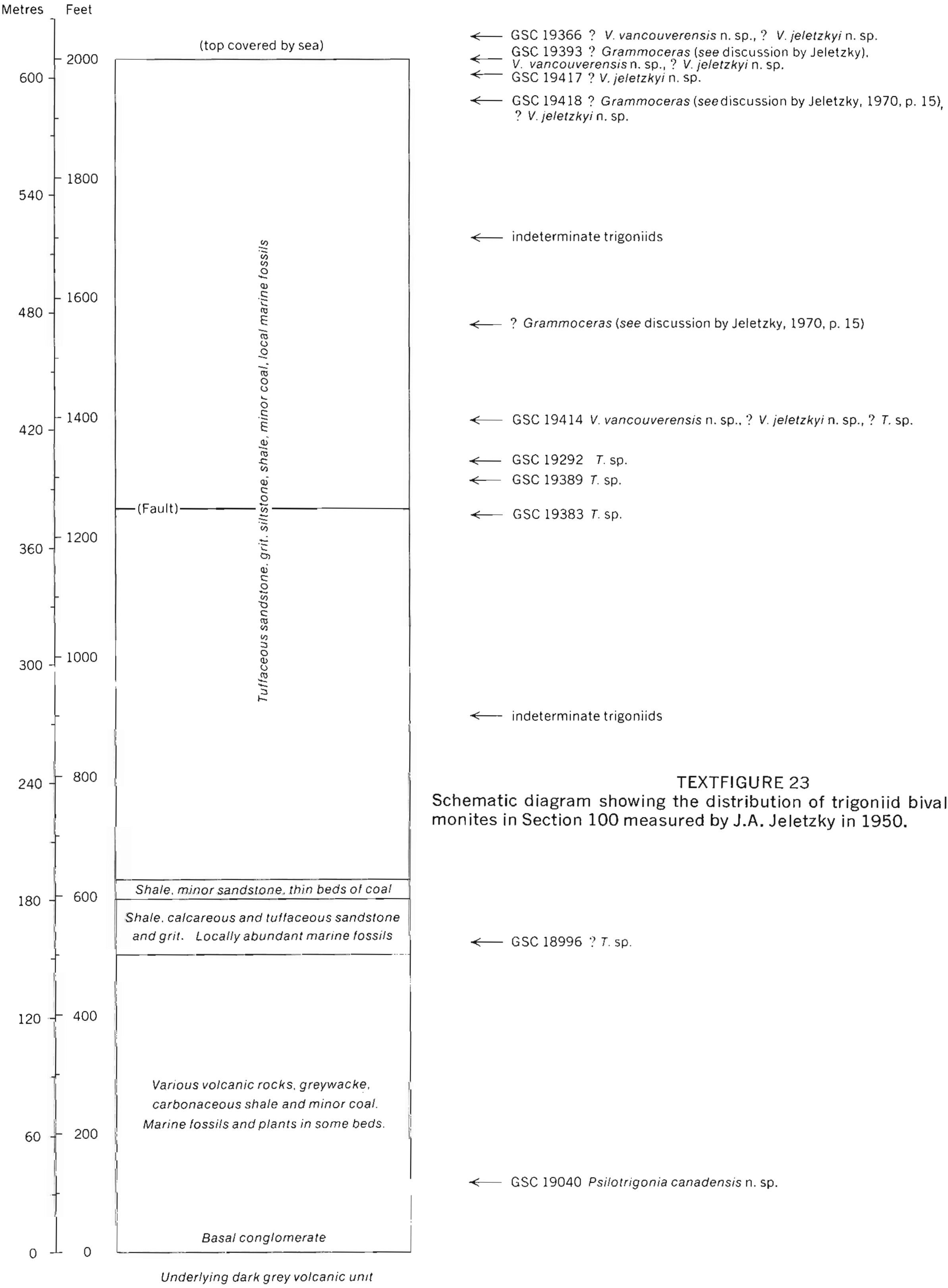
The unit yielding *V.* cf. *V. coatesi* n. sp. from Cowichan Lake area (Textfig. 1, loc. 5) tentatively is assigned a Toarcian age on the basis of the probable Toarcian age of *V. coatesi* n. sp. of Manning Park.

Affinities of Fauna

Juvenile stages of *V. vancouverensis* n. sp., *V. jeletzkyi* n. sp., and *V. coatesi* n. sp. have more or less pseudoconcentric costae. In the late growth stages, these species develop V-shaped costae where the posterior ends of the pseudoconcentric parts of the costae cut ventrally and diagonally across the growth lines in the posterior direction. In these respects, the three species are similar to the type species of *Vaugonia*, *V. veronica* Crickmay, and are morphologically intermediate between simple forms such as '*Trigonia*' *gryphitica* Moricke and more complicated ones like *V.* (*Hijitrigonia*) spp. (*see* Moricke, 1895; Kobayashi and Mori, 1955). At present, these morphological features do not appear to have biostratigraphic value other than being indicators of probable Early Jurassic age. The gross similarities of the North American Early Jurassic species to described Japanese, South American, and European '*Vaugonia*' species also do not permit detailed correlation.

The Canadian *Vaugonia* spp. described herein are similar to South American and Japanese forms but are not identical; *Psilotrigonia canadensis* n. sp. and *Trigonia* sp. of Vancouver Island have closer affinities with British species (*see* Lycett, 1872–79).

The similar biostratigraphic ranges of *V. vancouverensis* n. sp. and related forms from Nevada, Oregon, and central British Columbia indicate the biostratigraphic potential of some trigoniid bivalves even over wide areas. The morphologic similarity of these species also may indicate open-



TEXTFIGURE 23
Schematic diagram showing the distribution of trigoniid bivalves and ammonites in Section 100 measured by J.A. Jeletzky in 1950.

marine connections between, if not paleogeographic proximity of, these areas.

Systematic Paleontology

All types are stored in the collections of the Geological Survey of Canada, Ottawa. The cited GSC fossil localities are described in the Appendix. Where a question mark precedes the locality reference, the species assignment is questionable.

Morphological terms and generalized examples of the genera described are given in Textfigure 24.

Subclass **PALAEOHETERODONTA** Newell 1965

Order ***TRIGONIOIDA*** Dall 1889

Superfamily TRIGONIACEA Lamarck 1819

Family TRIGONIIDAE Lamarck 1819

Genus ***Psilotrigonia*** Cox 1952

Psilotrigonia Cox, 1952, 1969.

Type species. *Trigonia beesleyana* Lycett, 1874; Middle Bajocian, England.

Diagnosis. Posterior area wide, regularly and obliquely striated. Escutcheon very small, or apparently absent. Marginal carina a simple edge. Flank subdivided into anterior half with pseudoconcentric or concentric costae, and posterior half, smooth or with growth lines.

Discussion. The genus *Psilotrigonia* was considered monotypic until Nakano (1957) described *P. sanchuensis* from the Aptian of Japan. He suggested that the following forms also belong to the genus: Lycett's immature '*T. excentrica* Parkinson' (Lycett, 1874, Pl. 20, fig. 6) from the upper lower Cretaceous Greensand of England, *Trigonia semiculta* Forbes *in* Stoliczka (1871, Pl. 15, figs. 19, 22, 23, and 27) from the Cretaceous of India, and *Trigonia beyrichi* Krumbeck (1906, Pl. 8, figs. 5a, b) from the lower Turonian of Tripoli, North Africa. Their stratigraphic and geographic distribution patterns were summarized by Cox (1969).

Only *P. beesleyana* (Lycett) and *P. canadensis* n. sp. exhibit both the characteristic smooth posterior part of the flank and the diagonally costellate posterior area upon which basis Cox erected the genus (*see* Cox, 1952, 1969). These forms are sufficiently different in age and morphology from the Cretaceous forms mentioned above to be treated as a separate species group, if not as a different genus, in order not to disguise their biostratigraphic potential and possible phylogenetic significance. Treated this way, the *P. beesleyana–canadensis* species group is known only from Lower Pliensbachian to Middle Bajocian rocks in England and in British Columbia, and remains a rare and very poorly understood atypical Jurassic group.

Kobayashi and Mori (1954) and Kobayashi (1957) united *Psilotrigonia* with *Laevitrigonia* Lebkuchner and *Liotrigonia* Cox to form the *Laevitrigonia* Section of Subfamily Trigoniinae Kobayashi 1954. Nakano (1961, 1963) reorganized Kobayashi's Trigoniinae into two other subfamilies – Trigoniinae and Frenguelliellinae Nakano 1960 (Nakano, 1961) or Rutitrigoniinae van Hoepen 1929 (Nakano, 1963), and placed the *Laevitrigonia* Section, including *Laevitrigonia*, *Liotrigonia*, and *Psilotrigonia* into the latter. Because *Psilotrigonia* is distinctive in having diagonal costellae on the area and no antecarinal sulcus, Kobayashi (1957) retracted his earlier suggestion that *Psilotrigonia* evolved through a *Laevitrigonia* stage from *Trigonia*. Indeed, *Psilotrigonia* is unlike other trigoniids of the Jurassic, as already pointed out by Lycett (1872–1879, p. 92), and its affinities remain undetermined.

Cox (1952) distinguished *Psilotrigonia* from the rather similar Cretaceous genus *Rutitrigonia* van Hoepen 1929, the former having a less pyriform outline, a better defined marginal carina, and a broader ornamented area.

Because juvenile '*Trigonia*' *excentrica* Parkinson (*see* Lycett, 1874, Pl. 20, fig. 6 for example) has diagonal costellae on the area, Kobayashi and Mori (1954) and Kobayashi (1957) concluded that '*Trigonia*' *excentrica* passes through a *Psilotrigonia*-like phase in its ontogeny, and Kobayashi suggested a close phylogenetic relationship between the two species groups. Kobayashi (1957, p. 59) suggested that the *excentrica* group evolved from *Trigonia* through *Psilotrigonia*, and that the *excentrica* group should thus be separated from *Rutitrigonia*, in which it is placed by current authors, because *Rutitrigonia* does not show any evidence of diagonal costellae on the area. He (ibid., p. 57) pointed out the previous inclusion of the *excentrica* group, with *Psilotrigonia* and *Laevitrigonia* (the *gibbosa* group), in the Glabrae or Laeves Section of *Trigonia* sensu lato, and cited Lycett's (1874) Plate 20, figure 6 as evidence of their relationship. Savel'ev (1958) followed Kobayashi, considering *Psilotrigonia* to be an early derivative from a basic *Laevitrigonia* stock which later produced *Laevitrigonia*, *Nipponitrigonia* Cox, and *Quoiecchia* Crickmay. Savel'ev (ibid., Fig. 8) shows genera such as *Rutitrigonia* and *Megatrigonia*, as well as those with diagonal ornament on the area, such as *Apiotrigonia*, *Pterotrigonia*, *Linotrigonia*, *Oistotrigonia*, and *Scabrotrigonia*, as having originated from the same stock.

As discussed above, because of the diagonal costellation of the posterior area of *Psilotrigonia*, neither *Trigonia* nor *Laevitrigonia* appear to have been ancestral to *Psilotrigonia* which must be considered cryptogenic until more suitable ancestors are found. Thus the Cretaceous genera named above cannot be considered to be derivatives from *Trigonia* or *Laevitrigonia* through a *Psilotrigonia*-like phase. Indeed, only '*Trigonia*' *excentrica*, of the Cretaceous forms mentioned above, resembles *Psilotrigonia*. The other diagonally costellate Cretaceous genera appear to have developed their diagonal costellae of the posterior area secondarily from *Myophorella*-like or *Vaugonia*-like ancestors.

Discussions of the affinities of the Upper Jurassic species from New Zealand assigned to *Psilotrigonia* by Fleming (1964, p. 201) must await more complete description and illustration. Tentatively, it appears to be closely allied with '*Trigonia*' *excentrica* Parkinson.

Psilotrigonia canadensis new species
Plate 8, figure 1

Material and occurrence. A single complete but poorly preserved specimen (holotype, GSC 41562) and a few fragments on the same bedding plane; GSC locality 19040, Lower Pliensbachian beds of the Pliensbachian–Toarcian Greywacke Unit, western Vancouver Island. Shell material not preserved, external sculpture poorly preserved, being diagenetically superimposed upon internal moulds.

Description of holotype. Shell 40 mm long, 30 mm high. Umbos one third to one quarter length of shell from anterior. Outline ovate, narrowing slightly to posterior. Shell gently convex in cross-section.

Posterior area separated from flank by very slight angle, following straight line along which costellae of area end abruptly. Area ornamented by diagonal, finely and evenly spaced, relatively faint costellae that are slightly curved near umbos, otherwise straight, becoming slightly wider spaced to posterior. Faint growth lines intersect costellae. Flank divided into two along a more or less straight, dorsoventral locus about one fifth of length of shell from anterior and which nearly coincides with position of anterior tooth of hinge structure. To anterior, costae regular, finely and evenly spaced, concentric; to posterior, flank smooth except very near posterior end where a few diagonal costellae of area extend onto flank as concentric costae, fading anteriorly within a few millimetres. In latest growth stages, a few concentric costae extend across otherwise smooth anterior half of flank.

Remarks. Psilotrigonia canadensis differs from *P. beesleyana* (Lycett) in having somewhat more extensive and more regular concentric costae on the flank, and considerably coarser, straighter costellae on the posterior area (*see* Lycett, 1872–79). The costellae of the area become coarser in the posteroventral direction and they do not appear to bifurcate. The costae of the flank meet the plane of commissure nearly at right angles in *P. beesleyana* (they are 'pseudoconcentric'), but they are nearly concentric in *P. canadensis. Psilotrigonia beesleyana* is slightly larger and more strongly elongated than the Canadian species. *Psilotrigonia canadensis* has a longer dorsal margin, shorter posterior margin, less distinct posteroventral corner, and more rounded anterior margin.

Genus ***Trigonia*** Bruguière 1789

Trigonia Bruguière (1789, ref. *in* Lebküchner, 1932); Nakano, 1961.
Trigonia (*Trigonia*) Cox, 1969.
Lyridon Sowerby, 1823.
Lyriodon Bronn (1834, ref. *in* Lebküchner, 1932); Lebküchner, 1932.
Lyrodon Goldfuss (1837, ref. *in* Lebküchner, 1932).

Type species. *Venus sulcata* Hermann, 1781 (*see* Crickmay, 1932; Cox, 1969); Upper Lias, Alsace.

Diagnosis. Posterior area with reticulate ornament due to intersecting radial and concentric costellae. Costae of flank pseudoconcentric. More or less well developed, inequivalve condition in most species. Distinct antecarinal groove in left valve matching marginal carina of right valve where they meet at plane of commissure. Postcarinal groove in right valve. Posterior area, flank, escutcheon, distinctly separated.

Discussion. As described above, the genus *Trigonia* is a well-defined, relatively homogeneous, old and apparently early differentiated group. It includes those species earlier referred to the Costatae Section of Agassiz (1840). Its reticulate costellate posterior area separates it clearly from *Frenguelliella* Leanza (1942, p. 164) and *Frenguelliella* (*Kumatrigonia*) Tamura (1959, p. 213). Its relationships with *Latitrigonia* Kobayashi (Kobayashi and Tamura, 1957, p. 36) and *Pleurotrigonia* van Hoepen (1929, p. 33) are not well understood because of the somewhat unclear, apparently uncommon, and possibly transitional morphology of these last mentioned forms. Cox's (1969) inclusion of all these groups as subgenera of *Trigonia* discounts the probably strong phylogenetic significance of the reticulate area, the unique inequivalve condition, the apparently unique nature of the pedal elevator scar and the 'sub-umbonal notch' (*see* Savel'ev, 1958) and the strong differentiation of the posterior area into dorsal and branchial portions (Lycett, 1872–79). All these features characterize typical *Trigonia* sensu stricto.

Despite the large number of species of *Trigonia* described (*see* Lycett, 1872–79; Lebküchner, 1932; Nakano, 1961), the differentiating characteristics of each are relatively minor, strictly empirical, and not well understood in terms of phylogeny or natural taxonomic grouping. For these reasons, and because *Trigonia* sp., described herein, is similar to described *Trigonia* species except for minor differences of magnitudes of certain characteristics, open nomenclature is used for the time being.

Trigonia sp.
Plate 8, figures 2–6

Material and occurrence. Three moderately well preserved (hypotypes, GSC 41563–41565) and several poorly preserved specimens; GSC localities 19389, 19292, 19383, ?19414, ?18996, all in probably Pliensbachian beds of the Pliensbachian–Toarcian Greywacke Unit, western Vancouver Island.

Description of figured specimens. Shell small, largest being 32 mm long. Subtrigonal outline. Umbos directed approximately perpendicularly to dorsal margin and situated very near anterior. Anterior and ventral margins gently curved, meeting at a rounded, nearly right-angle corner. Shell strongly convex, with steep anterior and posterior sides near umbos.

Marginal carina a strong ridge, distinctly but somewhat irregularly corrugated. Transverse corrugations run short distance onto posterior area in left valve, but do not match growth lines, and are about three times as closely spaced as costae of flank. Smooth wide groove on left valve just anterior to marginal carina. Narrower one on right valve bears faint extensions of costae of flank. On right valve, indistinct smooth groove just posterior to marginal carina. Near umbos, surface of posterior area and flank meet at nearly a right angle along marginal carina; near posterior, they meet at obtuse but still distinct angle (120 to 130 degrees).

Posterior area with fine, more or less evenly spaced but somewhat irregular growth lines intersecting radial costellae that are more or less evenly spaced but of somewhat irregular strength. Intersections have small sharp nodes in some specimens. Median carina a slightly stronger crenulated costella, commonly with well-developed groove just dorsal; thus, dorsal half of area lies at lower level than other half. Inner carina a regularly corrugated costella, intermediate in strength between marginal and median carinae.

Escutcheon about one half length of dorsal margin, concave, with growth lines and suggestion of very fine radial costellae.

Flank with regular, strong, fine pseudoconcentric costae with intercostal spaces about three to five times as broad. At groove just anterior to marginal carina in left valve, ribs terminate abruptly, in some with slight but sharp point. Neither costae nor growth lines appear to curve ventrally near marginal carina, but growth lines are not seen clearly. No sulcus apparent anterior to marginal carina along ventral margin. Costae evenly spaced except in the 9.5 mm nearest the umbos where they become gradually closer together. All costae intersect the anterior margin and at increasingly more acute angles ventrally. They are very slightly convergent to the anterior. Costae faint and easily confused with growth lines in anteroventral corner of some specimens.

Remarks. Trigonia sp. described herein does not appear to be specifically identical with any other form known to the writer, differing from most described *Trigonia* species in the irregularity and relative coarseness of sculpture of the posterior area, the nearly smooth escutcheon, the irregular relationship between the corrugations of the marginal carina, the concentric ornament of the posterior area, and the relative strengths of the carinae. Nevertheless, it appears inadvisable to name the species formally because of the present poor understanding of species differentiation within the genus *Trigonia*.

Genus ***Vaugonia*** Crickmay 1930

Vaugonia Crickmay, 1930.
Vaugonia (*Vaugonia*) Cox, 1969.
Vaugonia (*Hijitrigonia*) Kobayashi *in* Kobayashi and Mori, 1955; Cox, 1969.

Type species. *Vaugonia veronica* Crickmay 1930, Middle Jurassic, British Columbia.

Diagnosis. Flank of adult subdivided into regions based on style of costae as follows: posterior region (Region C of Textfig. 24a) with diagonal costae sloping anteroventrally from marginal carina; central and anterior regions (D, E, F) with pseudoconcentric costae, commonly disrupted in ventral part of central region or with posteroventral sloping segments of costae in this part. Posterior area with concentric costellae. Posterior area, escutcheon, flank, distinctly separated.

Discussion. The genus *Vaugonia* is a member of a large group exhibiting diagonal costation on all or part of the flank and concentric costellation on the posterior area. Its general content is approximately that of the old Undulatae Section erected by Agassiz (1840). Lebküchner (1932) has pointed out the difficulty and apparent artificiality of separating taxonomically those forms with V-shaped costae from those with simply diagonal costae. Nevertheless, *V. veronica* is sufficiently distinct from the totally diagonally costate forms such as species of '*Myophorella*' Bayle that the genus *Vaugonia* is probably valid, even though transitional forms are known. At present, the writer differentiates *Vaugonia* from the *Myophorella* group, the former characterized by the central region of the flank which bears concentric costae (*see* Textfig. 24a). *Vaugonia coatesi* n. sp., for example, is referred to *Vaugonia* because it exhibits this feature whereas, in general aspect, it is similar to certain *Myophorella* species. Many species with the concentrically costate central region of the flank develop fine segmentation of the costae in the ventral part of that region (Region F of Textfig. 24a). The segments 'step' posteroventrally. This feature is exaggerated with growth of the shell and, in many species, continuous posteroventrally sloping costal segments are developed. Extreme forms exhibiting this last feature induced Kobayashi (Kobayashi and Mori, 1955) to erect the subgenus *Hijitrigonia*. The writer tentatively follows Cox (1969) in rejecting the name *Hijitrigonia* as being a description of a morphological character developed in the ontogeny of species, and not yet demonstrated to form a distinct phylogenetic stock.

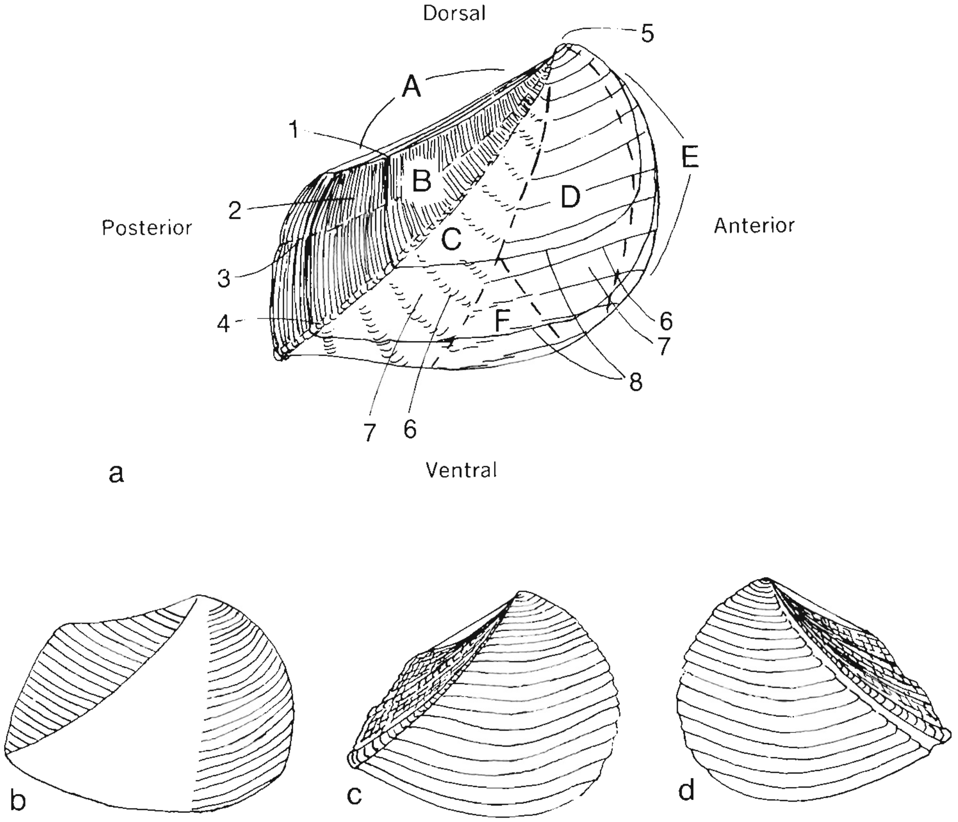
Orthotrigonia Cox (1952) is rejected from inclusion in *Vaugonia* by virtue of the absence of a region with concentric costation and the unusual early ontogenetic change from V-shaped to diagonal costation of the flank.

Vaugonia jeletzkyi new species
Plate 8, figures 7–12

Material and occurrence. Abundant specimens (including holotype GSC 41566 and paratypes GSC 41567–41571 from GSC loc. 19400) preserved as carbonaceous imprints on argillite. External and internal shell features superimposed on single surfaces. *Vaugonia jeletzkyi* occurs in probable Pliensbachian beds of the Pliensbachian–Toarcian Greywacke Unit of western Vancouver Island (GSC locs. 19400, 19371, 19295, ?19414, ?19380, ?19393, ?19366, ?19418, ?19417, ?19397). *Vaugonia jeletzkyi* is described from rocks in the same area as Section 100, but only poorly preserved specimens tentatively referred to this species occur with *V. vancouverensis* in that section. Where these two species have been positively identified, they do not occur together and their morphologic distinctions are clear. The stratigraphic association of the two species cannot be considered certain, but *V. jeletzkyi* tentatively is thought to occur above *V. vancouverensis* n. sp., and to overlap that species in range.

Description of figured specimens. Shell small, maximum length 25.5 mm. Subtrigonal outline. Truncated rostrate posterior. Anterior and anteroventral margins form smooth curve; dorsal and posteroventral margins straight. Umbos sharp, varying in position from very near anterior of shell to one quarter of length of shell from anterior. Most directed nearly perpendicularly to dorsal margin but they are somewhat posteriorly recurved on several specimens. Articulated valves with low, gently convex cross-section.

Marginal carina the narrow sharp edge of posterior area. Fine costellae of area extend to this edge, which may be



TEXTFIGURE 24. Simplified sketches of trigoniid shells showing major external morphological features described in text. a, generalized example of genus *Vaugonia* Crickmay, right valve. b, generalized example of genus *Psilotrigonia* Cox, right valve. c, d, generalized example of genus *Trigonia* Bruguière, right and left valves. Regions of the shell: A, escutcheon; B, posterior area; C–F, flank: C, region with diagonal or subradial costae or segments of costae; D, region with concentric (sensu Thompson, 1942, p. 825) costae or segments of costae; E, region where anterior ends of costae become nearly perpendicular to growth lines (costae are 'pseudoconcentric'); F, region, where concentric costae of region D become irregular and are commonly finely segmented, the segments 'stepping' ventrally in the posterior direction.

Other morphological characters: 1, inner carina; 2, concentric costellae of posterior area (they are diagonal in Textfig. 24b; radial and concentric costellae intersect to form a reticulate pattern in Textfig. 24c, d); 3, median groove or carina; 4, marginal carina (this is either a simple edge as in Textfig. 24b, or a distinct ridge as in Textfig. 24c, d); 4, distinct antecarinal groove characterizes the left valve of the genus *Trigonia* (*see* Textfig. 24d); 5, umbo; 6, costae of the flank; 7, intercostal spaces; 8, representative growth lines.

very finely tuberculate. Posterior area and flank meet at 80 degrees at umbo, but nearly coplanar to posterior. Anterior side of marginal carina a very narrow smooth region against which costae of flank abut. Slight antecarinal groove in some specimens.

Posterior area flaring rapidly, constituting one third to one half area of total shell in largest specimens. Area with very fine, evenly spaced, straight, transverse costellae. Poorly developed median groove. Costellae extend across it without interruption. Dorsal half of area very slightly elevated relative to branchial half in some specimens, the two coplanar in others. Inner carina a smooth ridge or very finely tuberculate. Escutcheon three quarters length of shell, somewhat concave, smooth or with very fine growth lines.

Flank with variable ornamentation. As many as 12 costae are present, as strong sharp ridges, smooth except for impressions of growth lines, tapering to points toward marginal carina. The two to four costae nearest umbo (until shell about 6.3 mm long) either slightly oblique or pseudoconcentric, abutting anterior margin at right angles. Later costae consisting of three segments joined along smooth curved loci, one near and parallel to anterior margin, the other down centre of flank. Anteriormost, shortest segments of costae meet anterior margin at nearly right angles. Central, relatively short segments of costae subconcentric, regularly spaced at 1 to 2 mm intervals, slightly irregular in many specimens, and may transect growth lines at very small angle, cutting ventrally to anterior or posterior. Posterior segments of costae ventrally change from subconcentric to dorsoventral, meeting antecarinal groove at increasingly acute angles, resulting in increasing sharpness of V-pattern, where middle and posterior segments meet. Posterior segments strongest on flank, commonly swollen to form row of incipient nodes near where they meet subconcentric segments. Posteriormost dorsoventral costal segments subparallel, abutting corrugated ventral margin at right angles. Subconcentric and dorsoventral segments of costae meet in simple V or over narrow interval in which they are more or less convoluted.

Remarks. Vaugonia jeletzkyi is not closely similar to any other known species. It is distinguished from *V. vancouverensis* n. sp. in having the sharp V-costation of the flank developed earlier. The posterior costal segments occupy more of the flank and are more strongly radiating. The V's are sharper as a result of the more acute angle at which the posterior segments leave the antecarinal groove. The ornamentation of the flank is more varied, that of the posterior area more consistent.

Apparently least deformed specimens have a long and posteriorly rostrate outline in contrast with Kobayashi's and Mori's (1955) species *V. kojiwa* and *V. geniculata*, and are distinguished further from the latter species in having smooth rather than tuberculate costae.

Vaugonia vancouverensis new species
Plate 8, figures 13–20

Material and occurrence. Abundant well-preserved specimens (including holotype GSC 41572 and paratypes GSC 41573, 41574 from GSC loc. 19404, and paratype GSC 41575 from GSC loc. 19409). *Vaugonia vancouverensis* is relatively common in probable Pliensbachian beds of the Pliensbachian–Toarcian Greywacke Unit of western Vancouver Island (GSC locs. 19404, 19409, 19414, 19393, ?19366).

Description of figured specimens. Shell small to medium, maximum length about 20 mm. Rounded subtrigonal outline. Ventral and anterior margins straight for short distance, meeting in broadly rounded curve. Small ventral sulcus just anterior to marginal carina. Dorsal margin mostly straight, concave near umbos, which project above it. Posterior end rostrate, straight, forming sharp angle with ventral margin. Umbos posteriorly recurved, most commonly situated one quarter to one third length of shell from anterior but near anterior in some specimens. Main part of shell gently convex, umbonal and anterior regions steep.

Marginal carina the simple narrow edge of posterior area. Its ventral side a narrow smooth zone, descending into shallow, sharp antecarinal groove at level of flank. Angle between flank and posterior area varies from approximately 60 degrees near umbo to 10 to 20 degrees at posterior.

Posterior area with transverse costellae, either straight and evenly spaced, or slightly irregular. Costellae of uniform density in most specimens, but degenerate into very fine, slightly irregular growth lines near posterior in some larger ones. Costellae uninterrupted across area in some specimens; in others slightly disrupted along line slightly dorsal of median position, where a very faint (median) groove may occur. Inner carina similar to marginal carina, a sharp edge between posterior area and escutcheon which is strongly depressed, groove-like. Escutcheon either smooth or with very faint growth lines, about three quarters length of dorsal margin.

Costae of flank more V-shaped with growth. Two or three costae nearest umbos pseudoconcentric with small node near centre of each. Intercostal spaces about twice thickness of costae.

Next six to eight costae (until shell about 16 mm high) slightly wider spaced, separated into three distinct segments. Posterior segments diagonal, either terminating sharply at posterior ends and forming margin of antecarinal groove, or tapering gradually within the groove. They meet groove at constant intervals, at angles near 90 degrees, diverging slightly. Posterior segments stronger than others, crenulated. Growth lines in intercostal spaces. Posterior segments meet corresponding concentric or subconcentric segments along curved locus running approximately down centre of flank. Posterior ends of concentric segments increasingly transect growth lines, becoming diagonal, presenting appearance of straight lines forming chords to anteroventral part of shell margin. The two segments meet in smooth curve, becoming more V-shaped ventrally, with row of faint nodes in some specimens. Concentric or subconcentric segments smooth and sharply ridged, becoming weaker and closer spaced ventrally in most specimens, but retaining strength and spacing in a few. At line where anterior end of flank descends sharply to plane of commissure, concentric segments join anterior segments of costae, which meet anterior margin of shell at right angles.

After shell height reaches about 16 mm, posterior diagonal segments and concentric segments of costae may meet in V-shaped junction, may be slightly offset from one another, or the concentric segments may die out to posterior. Where segments die out, narrow smooth space occupies region between the two segments. Posterior segments meet ventral margin at about 45 degrees. Latest concentric segments terminate to anterior in anteroventral curve of shell margin so anteriormost segments missing. In extreme cases, points of meeting of anterior ends of concentric costae with ventral margin, and points where concentric costae fade at posterior ends, approach each other and costae become concave ventrally, clearly nonconcentric.

Remarks. Vaugonia vancouverensis is distinguished from the Japanese *V. niranohamensis* Kobayashi and Mori in that the latter shows increasing sinuosity of the costae with growth and *V. vancouverensis* is more rostrate posteriorly. It differs from *V. yokoyamai* Kobayashi and Mori and most other Japanese Early Jurassic forms in being only incipiently tuberculate, and only so on the posterior segments of the costae, and in having only very fine rather than coarse costellae on the area. Differences between *V. vancouverensis* and *V. jeletzkyi* n. sp. were discussed under the description of the latter species.

The close resemblance of *V. vancouverensis* to specimens of *Vaugonia* that occur in beds of Late Sinemurian age in Nevada indicates an age for the Vancouver Island material that is more likely to be Pliensbachian than Toarcian. One specimen from Nevada appears to be identical with certain specimens of *V. vancouverensis*. Another fragmentary specimen is similar but has slightly coarser ribs than is typical of the Canadian species.

Vaugonia coatesi new species
Plate 8, figures 21–26

Material and occurrence. Abundant well-preserved external moulds (including holotype GSC 41576 and paratypes GSC 41577–41579 from GSC loc. 69415, paratypes 41580–41581 from Coates' loc. CU-66-76, paratype 41582 from GSC loc. 69414). *Vaugonia coatesi* is abundant in a probable Toarcian greywacke unit of Manning Park (GSC locs. 69415, 69414, 89417, and Coates' collection bearing field number CU-66-76).

Description of figured specimens. Shell small, only a few specimens reaching a length of 20 mm. Outline subquadrangular to crudely semicircular or rounded subtrigonal, mainly reflecting variation in relative width of posterior area. Anterior and ventral margins form smoothly rounded paraboloid curve in some specimens, nearly straight and meeting in rounded obtuse angle in others. Umbos near anterior, slightly posteriorly recurved. Shells gently convex, steep sides near umbos.

Marginal carina a sharp narrow ridge near umbos, to posterior, the rounded edge of posterior area, level with costae of flank which either abut it directly or are separated by very narrow antecarinal groove. Carina with closely spaced transverse corrugations which are varices at ends of each or every second costella of posterior area. Posterior area with fine, regular, concentric costellae becoming finer and less even with growth. Faint median groove, absent in early parts of some specimens, generally not disrupting costellae. Inner carina a sharp ridge of equal or greater strength than marginal carina, similarly ornamented with varices which are, however, more pointed, stronger, slightly more widely spaced. Escutcheon relatively wide, gently concave, slightly depressed, with growth lines.

Costae of flank divided into three segments even in earliest pseudoconcentric stages: one adjacent to marginal carina, second in centre of flank, third in narrow region at anterior of shell. These three regions of flank separated in most specimens by loci joining more or less distinct points of flexure of costae. Some specimens with slight nodes on costae where they cross loci. Costae maintain crudely smooth but nevertheless segmented curvature in 10 mm nearest umbos, where posterior segments of costae meet marginal carina at increasingly more acute angles. Central segments nearly concentric, increasing spacing ventrally. Anterior segments nearly perpendicular to anterior margin, becoming concentric within about 6 mm of umbo. Strength of costae relatively constant throughout flank of individual shells, and from one shell to another. Costae near umbos very finely tuberculate, tubercles aligned in fine costation radiating from umbo.

Angle between posterior and central segments of costae increases to approximately 90 degrees in later growth stages. Central segments in mature growth stages somewhat irregular, closer spaced adventrally, with anterior ends segmented and somewhat irregular, segments commonly 'stepped' ventrally to posterior. Anterior ends of central segments crowded, meeting anterior margin at acute angles. Posterior segments finely tuberculate in late growth stages, other segments fine, sharp, smooth.

Remarks. Vaugonia coatesi differs from *V. vancouverensis* n. sp. in having a smaller posterior region of costal segments, in being finer ribbed, in being less rostrate posteriorly, and in the commonly more acute angle at which the costae leave the marginal carina. The posterior ends of the central segments of costae of the flank begin to cut ventrally at later stages of growth and do so less commonly than in *V. vancouverensis*. The early costae and the posterior segments of adult costae are less clearly tuberculate in *V. vancouverensis*.

Vaugonia cf. *V. coatesi* new species
Plate 8, figures 27, 28

A few well-preserved external moulds (including hypotypes GSC 41583, 41584) from the Cowichan Lake area of Vancouver Island (GSC loc. 89090) are very similar to *V. coatesi* of Manning Park, but differ in having a more distinct antecarinal groove and more distinct, slightly irregular, separation of the costae of the flank near the umbo into three distinct segments. At present, these features do not appear to warrant specific separation of the forms from the two areas. The presence of *V.* cf. *V. coatesi* indicates a probable Toarcian age for the containing unit.

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APPENDIX

Locality register for cited GSC fossil localities

West Coast, Vancouver Island

GSC loc.

18996. (Field no. 100/8). J. A. Jeletzky, 1950. About 1,200 yards north of mouth of Tatchu Creek on main shore below high tide mark. Lat. 49°53′32″N, long. 127°10′35″ W; *Trigonia ?* sp.

19040. (Field no. 100/9). J. A. Jeletzky, 1950. 1,100 yards north of mouth of Tatchu Creek; taken from lowermost beds (8–10 ft.) of sandstone horizon. Lat. 49°53′31″N, long. 127°10′30″W; *Psilotrigonia canadensis*.

19292. (Field no. 100/46). J. A. Jeletzky, 1950. 25–30 feet south of tip of small point southeast of Gregoire Point, in rocky fringe surrounding point about 100 feet from its tip, below high-tide mark. Lat. 49°53′45″N, long. 127°10′50″W; *Trigonia* sp.

19295. (Field no. 85/6). J. A. Jeletzky, 1950. West side of Peculiar Point at north shore of Esperanza Inlet. A bed of dark grey fissile shale at outer margin of rocky beach. Lat. 49°51′34″N, long. 127°05′27″W; *Vaugonia jeletzkyi*.

19366. (Field no. 100/66). J. A. Jeletzky, 1950. First rocky islet off tip of small point southeast of Gregoire Point on northwestern end of islet. Lat. 49°53′45″N, long. 127°10′50″W; *Vaugonia jeletzkyi ?*, *V. vancouverensis ?*

19371. (Field no. 120/2). J. A. Jeletzky and R. V. Best, 1950. About 35–40 feet north of small creek just north of Gregoire Point, tidal shelf 90–100 feet beyond high-water mark. Lat. 49°54′20″N, long. 127°11′24″W; *Vaugonia jeletzkyi*.

19380. (Field no. 116/1). J. A. Jeletzky and R. V. Best, 1950. Impure tuffaceous limy grit at point nearest shore, centre of shallow, easterly reef between river and Gregoire Point. Lat. 49°54′08″N, long. 127°11′18″W; *Vaugonia jeletzkyi ?*

19383. (Field no. 100/42a). J. A. Jeletzky, 1950. About 50–60 feet south of very tip of small point southeast of Gregoire Point, from rocky fringe surrounding the point, below high-tide mark. Lat. 49°53′43″N, long. 127°10′50″W; *Trigonia* sp.

19389. (Field no. 100/44b). J. A. Jeletzky, 1950. About 60–65 feet south of very tip of small point southeast of Gregoire Point, from rocky fringe surrounding the point, below high-tide mark. Lat. 49°53′43″N, long. 127°10′50″W; *Trigonia* sp.

19393. (Field no. 100/65). J. A. Jeletzky, 1950. About 200 feet southeast from northwestern end of rocky islet off small point southeast of Gregoire Point, beyond shallow channel. lat. 49°53′43″N, long. 127°10′50″W; *Vaugonia vancouverensis*, *V. jeletzkyi ?*, and *Grammoceras ?* sp.

19397. (Field no. 122/1). J. A. Jeletzky, 1950. Northwestern shore of broad bay between Mushroom Point and the one farther south. Approximately lat. 49°55′30″N, long. 127°12′10″W; *Vaugonia jeletzkyi ?*

19400. (Field no. 120/3). J. A. Jeletzky and R. V. Best, 1950. About 175 yards north of small creek north of Gregoire Point, on shore about 40 feet below high-water mark, opposite a small valley 20 yards wide. Approximately lat. 49°54′55″N, long. 127°11′56″W; *Vaugonia jeletzkyi*.

19404. (Field no. 120/8). J. A. Jeletzky and R. V. Best, 1950. Eastern end of beach extending east from small point north of Gregoire Point, 50 yards west of cave terminating beach; a small grit point. Sample obtained 1 foot east of base of grit. Lat. 49°54′36″N, long. 127°11′30″W; *Vaugonia vancouverensis*.

GSC loc.

19409. (Field no. 121/1). J. A. Jeletzky, 1950. 45 feet west of limestone reef running south from beach east of small point north of Gregoire Point, middle of boulders below high-water mark, centre of 70 feet of black shale. Lat. 49°54′37″N, long. 127°11′37″W; *Vaugonia vancouverensis*.

19414. (Field no. 100/50b). J. A. Jeletzky, 1950. About 100 feet at bearing 240 degrees, from the very tip (sandspit) of small point southeast of Gregoire Point, from rocky fringe around the point. Lat. 49°53′43″N, long. 127°10′50″W; *Vaugonia vancouverensis*, *V. jeletzkyi ?* and *Trigonia ?* sp.

19417. (Field no. 100/64). J. A. Jeletzky, 1950. About 200 feet southeast from northwest end of rocky islet off small point southeast of Gregoire Point (beyond narrow channel), from about 7–8 feet of shale and siltstone. Lat. 49°53′43″N, long. 127°10′50″W; *Vaugonia jeletzkyi ?*

19418. (Field no. 100/63). J. A. Jeletzky, 1950. About the middle of first rocky islet off small point southeast of Gregoire Point (beyond first channel) at north side in small trough occupied by shale. Lat. 49°53′44″N, long. 127°10′55″W; *Vaugonia jeletzkyi ?* and *Grammoceras ?* sp.

Cowichan Lake Area, Vancouver Island

89090. (Field no. 70–19S–ME). J. E. Muller, 1970. F. P. Logging Road C5, 7 miles east of Nitinat Lake. Lat. 48°49′55″N, long. 124°31′25″W; *Vaugonia* cf. *V. coatesi*.

Manning Provincial Park

69414. (Field no. CU–65–230). J. A. Coates, 1965. Elevation 4,850 feet on steep face of burnt-over ridge 2.5 miles north of Hope-Princeton Highway and east of Cambie Creek. Lat. 40°08′25″N, long. 120°50′25″W; *Vaugonia coatesi*.

69415. (Field no. CU–65–230C). J. A. Coates, 1965. Elevation 5,450 feet on steep face of burnt-over ridge 2.5 miles north of Hope–Princeton Highway and east of Cambie Creek. Lat. 49°08′32″N, long. 129°50′13″W; *Vaugonia coatesi*.

89417. (Field no. PU–27–72–4F). T. P. Poulton, 1972. Near southern end of west-facing burnt-over hillside north of Allison Pass, about elevation 5,250 feet. Lat. 49°08′32″N, long. 120°50′13″W; *Vaugonia coatesi*, *Grammoceras ?* sp. indet., *Weyla* sp. indet., belemnites.

Field no. CU–66–76 Lithologically and faunally identical with GSC collections 69414, 69415, 89417, and contains a note indicating that it was collected by J. A. Coates in 1966 as a supplement to GSC collection 69414; locality cited *in* Coates (1974, p. 81, Fig. 12) as "Pebbly volcanic sandstones at elevation about 5000′ on burnt-over hill east of Cambie Creek. 49°08′35″N., 120°50′15″W. 2.4 miles NE of highways department depot at Allison Pass;" *Vaugonia coatesi*.

PLATE 8

Psilotrigonia canadensis new species (Page 45)

Figure 1. Lateral view of left valve and oblique view of right valve of holotype GSC 41562; GSC loc. 19040; x1.

Trigonia sp. (Page 45)

Figures 2–4. Lateral view of right valve, posterodorsal view of posterior area and escutcheon, and dorsal view of umbo and anterior margin of hypotype GSC 41563; GSC loc. 19389; x1.

Figure 5. Lateral view of left valve of hypotype GSC 41564 from same locality; x1.

Figure 6. Lateral view of right valve of hypotype GSC 41565 from same locality; x1.

Vaugonia jeletzkyi new species (Page 46)

Figure 7. Lateral view of left valve of holotype GSC 41566; GSC loc. 19400; x2.

Figures 8–10. Lateral views of left valves of paratypes GSC 41567, 41568, 41569, from same locality; x2.

Figures 11, 12. Lateral views of right valves of paratypes GSC 41570, 41571, from same locality; x2.

Vaugonia vancouverensis new species (Page 48)

Figures 13–16. Lateral view of left valve, dorsal view of umbo and posterior area, ventral view, lateral view of right valve, holotype GSC 41572; GSC loc. 19404; x2.

Figure 17. Lateral view of right valve of paratype GSC 41573 from same locality; x1.

Figures 18, 20. Anteroventral view, lateral view of left valve and oblique view of fragmentary right valve, paratype GSC 41575; GSC loc. 19409; x1.

Figure 19. Lateral view of right valve and oblique view of left valve of fragmentary paratype GSC 41574; GSC loc. 19404; x1.

Vaugonia coatesi new species (Page 49)

Figure 21. Lateral view, latex cast of right valve of paratype GSC 41577; GSC loc. 69415; x2.

Figure 22. Lateral view, latex cast of right valve of holotype 41576 from same locality; x1.

Figure 23. Lateral view, latex cast of left valve of paratype GSC 41580; locality CU-66-76 of J. A. Coates; x1.

Figure 24. Lateral view, latex cast of left valve of paratype GSC 41582; GSC loc. 69414; x1.

Figure 25. Lateral view, latex cast of left valve of paratype GSC 41581; locality CU-66-76 of J. A. Coates; x1.

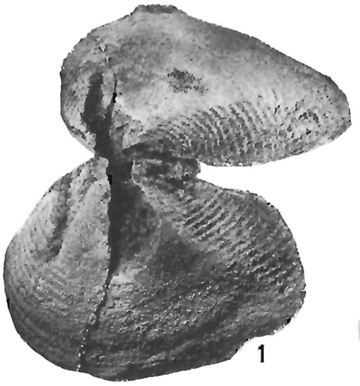
Figure 26. Lateral view, latex cast of right valve of paratype GSC 41578, and a juvenile accessory specimen, paratype GSC 41579; GSC loc. 69415; x1.

Vaugonia sp. cf. *V. coatesi* new species (Page 49)

Figure 27. Lateral view, latex cast of left valve of hypotype GSC 41583; GSC loc. 89090; x1.

Figure 28. Lateral view, latex cast of right valve of hypotype GSC 41584; same locality; x1.

PLATE 8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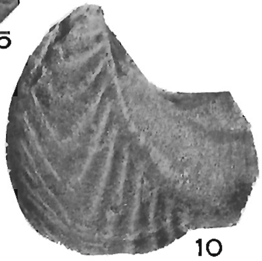
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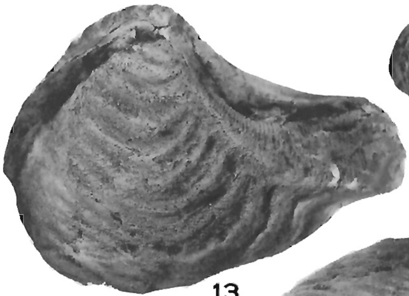
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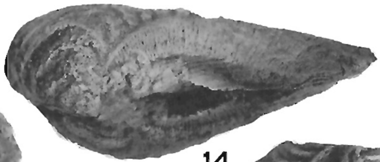
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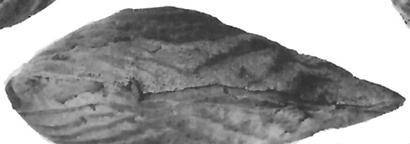
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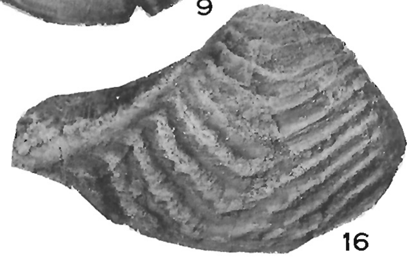
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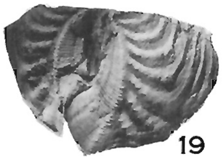
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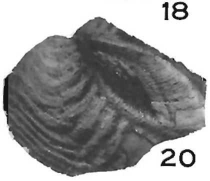
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MIOSPORES AND MEGASPORES FROM THE LOWER CRETACEOUS MATTAGAMI FORMATION OF ONTARIO

by W.S. Hopkins, Jr. and A.R. Sweet

Abstract

The age, vertical distribution, and paleoecology of the palynomorphs found within the Mattagami Formation are presented. An age of Early Albian is thought to be most probable although an Aptian or early Middle Albian cannot be excluded. The frequency distribution of the megaspore species indicates a change in paleoenvironment within the Mattagami Formation. This makes possible the differentiation of two palynologically distinct lignite units. One new combination, *Bacutriletes onodios* (Harris, 1961) n. comb., is proposed.

Résumé

L'âge, la distribution verticale et la paléoécologie des palynomorphes découverts dans la formation Mattagami sont discutés. Un âge Albien inférieur semble être le plus probable bien que la possibilité d'un âge Aptien ou début Albien moyen ne puisse être écartée. La fréquence de distribution des espèces de megaspores indique l'existence d'un changement de paléo-environnement à l'intérieur de la formation Mattagami. De ce fait deux unites lignitiques différentes d'un point de vue palynologique ont été reconnues. Une nouvelle combinaison, *Bacutriletes onodios* (Harris, 1961) n. comb., est proposée.

Introduction

The Mattagami Formation is a discrete, clastic sedimentary unit occurring only in the Moose River Basin, southwest of James Bay, northeastern Ontario. This formation is thin, having a maximum known thickness of 170 feet (51 m). Early geological studies indicated that it covered a geographical area of about 7,000 square miles (10920 km^2), but the results of more recent work suggest 2,000 square miles (3120 km^2) as being a more reasonable figure (L.L. Price, pers. com.). Exposures are poor and widely scattered because of the subdued topography.

At this time, published geological information pertaining to the Mattagami Formation is limited. Some general information is available in publications by Keele (1919, 1920) who first described the formation; further discussion is given by Bell (1928), Radforth (1958), and Sanford and Norris (1970). L.L. Price, of the Geological Survey of Canada, is preparing a manuscript in which he discusses the geology of this formation based on more recent field work and the study of cores from boreholes.

The Mattagami Formation unconformably overlies the eroded edges of Silurian, Devonian, and, locally, Precambrian rocks. According to Sanford and Norris (1970, p. 145): "The lower part consists of dark grey to black fire clays, and brownish to yellowish micaceous sands with fragments of carbonized plant stems and thick seams of lignite, succeeded by a sequence of varicolored plastic clay and white quartz sand and clay."

Acknowledgments

The writers wish to express their appreciation for the help of H. Johnson and S. Pickering in preparing the samples. Useful discussions were held with L.L. Price regarding the geology of the Mattagami Formation. L.L. Price and P.R. Gunther critically read the manuscript.

Sample Locations

The samples were obtained from the boreholes and pit whose locations are listed below.

Onakawana lignite pit:	50°36′00″N; 81°23′00″W
Hole number 68-38:	50°36′00″N; 82°31′12″W
Hole number 68-39:	50°35′48″N; 82°30′42″W
Hole number 68-42:	50°35′36″N; 82°30′12″W
Hole number 68-43:	50°35′26″N; 82°28′56″W

Megaflora

The earliest known study of the fossil floras from the Mattagami Formation was from a collection made by Keele in 1919. This material was sent to the United States Geological Survey for study but the fossils were so fragmentary and poorly preserved that it "was impossible to determine even the genera with certainty." It was, however, suggested that most of the large fragments were of a leaf of "Taeniopteroid (Bennettitales) aspect." Bell (1928) reported on material gathered from sand and shale from two localities along Mattagami River. Preservation was poor but, besides stems of unidentified lignified wood, the following five form-genera of leaves were identified: *Nilssonia* (Cycadales), *Pityophyllum* (Bennettitales), *Brachyphyllum* (conifer; Bell suggests affinities with the Araucariaceae, or possibly *Sequoia*), *Cladophlebis* (fern, probably related to the Osmundaceae), and *?Onychiopsis* (probably a fern).

Radforth (1958) conducted anatomical studies of woody fragments and concluded (p. 50) that "Both the large and small predominantly woody examples described are unquestionably coniferous and from the evidence presented it would appear they are generically similar." He tentatively assigned the wood fragments to several species of *Cupressinoxylon* (Cupressaceae), and further described several species of fossil fungi associated with the coniferous wood.

Microflora

Rouse (1956) described a comparatively large number of spores and pollen from samples taken from the open face of the Onakawana lignite pit (now no longer exposed) and from outcrops on Mattagami and Abitibi Rivers. His microflora is similar basically to the one discussed here, but included also a number of modern-looking angiosperm pollen. Rouse (pers. com.) now believes that the angiosperm pollen was contamination from overlying Pleistocene material and/or from the dense, extant vegetation that covers the area.

Radforth and Rouse (1956) presented some general Cretaceous palynomorph data from selected localities across Canada, including the Mattagami Formation. The data were obtained, presumably, from the results of studies reported in Rouse (1956).

The results of the most recent palynological work is presented here. Twenty-seven samples of well cuttings from four boreholes, representing stratigraphic intervals from top to bottom of the formation, were examined in detail. These samples were collected by L.L. Price and are from boreholes 68-38, 68-39, 68-42, and 68-43 drilled in 1968 by Manalta Coal Limited, subsequent to Operation Winisk, an intensive field study by the Geological Survey of Canada in 1967. Two additional samples, collected by L.L. Price from lignite stock piles adjoining the Onakawana lignite pit, also were examined.

In this paper specific samples are referred to by the letter "C" followed by a number. These are GSC locality numbers whose locations are indicated on the stratigraphic sections shown by Textfigure 25.

Miospores

No detailed taxonomy is given because, with the exception of *?Protopicea*, all miospores are well known, and have been described and illustrated in numerous publications. Palynomorphs present are listed below, together with rough estimates of the abundance and distribution. Generally, the microflora appears to be essentially the same from top to bottom of the formation. The variations that occur seem to be the result of preservation or, in some cases, low frequency.

Division BRYOPHYTA
- Family SPHAGNACEAE
    - *Stereisporites antiquasporites* (Wilson and Webster) Dettmann
        - Relatively uncommon, but occurs in all samples
    - *Cingutriletes clavus* (Balme) Dettmann 1963
        - Rare, but occurs in all samples

Division LYCOPODOPHYTA
- Family LYCOPODIACEAE
    - *Lycopodiumsporites* sp.
        - Variable, but occurs in all samples
    - *Sestrosporites pseudoalveolatus* (Couper) Dettmann 1963
        - Rare, found only in C-17275

Division PTEROPHYTA
- Family POLYPODIACEAE and/or DENNSTAEDTIACEAE
    - *Laevigatosporites* sp.
        - Relatively common in all samples
- Family OSMUNDACEAE
    - *Osmundacidites wellmanii* Couper 1953
        - Common in all samples
    - *Baculatisporites comaumensis* (Cookson) Potonié 1956
        - Common in all samples
- Family GLEICHENIACEAE
    - *Gleicheniidites senonicus* Ross 1949
        - Common in all samples
- Family CYATHEACEAE or DICKSONIACEAE
    - *Kuylisporites lunaris* Cookson and Dettmann 1958
        - Rare, observed only in C-29911
    - *Cyathidites minor* Couper 1953
        - Relatively common in all samples
- Family SCHIZAEACEAE
    - *Cicatricosisporites* spp.
        - Abundant in all samples
    - *Appendicisporites* spp.
        - Relatively common in all samples
    - *Trilobosporites apiverrucatus* Couper 1958
        - Rare, but present in all samples
    - *Lygodium* cf. *L. reticulosporites* Rouse 1962
        - Rare, but present in all samples
    - *Chomotriletes fragilis* Pocock 1962
        - Rare, seen only in C-16231

SPORES – *Incertae sedis*
- *Converrucosisporites* sp.
    - Rare, but present in all samples
- *Densoisporites* sp.
    - Rare, seen only in C-29913 and C-29919

Division GNETOPHYTA
- Family EPHEDRACEAE
    - *Ephedra* sp.
        - One specimen only seen, C-17225

Division CYCADOPHYTA
- Order BENNETTITALES
    - *Cycadopites* cf. *C. scabratus* Stanley 1965
        - Rare, but appears to be present in all samples

- Division PTERIDOSPERMOPHYTA
  - Family CAYTONIACEAE
    - *Vitreisporites pallidus* (Reissinger) Nilsson 1958
      - Common in all samples

- Division CONIFEROPHYTA
  - Family PINACEAE
    - *Tsugaepollenites mesozoicus* Couper 1958
      - Common in all samples
    - *Laricoidites* cf. *L. magnus* (Potonié) Potonié, Thomson, Thiergart
    - *?Protopicea* sp.
      - Seen only in C-29848, C-29849, and C-29914. Probably more common but easily destroyed in processing.
    - *Alisporites* sp.
      - Common in all samples
    - cf. *Phyllocladidites* sp.
      - Relatively common in all samples
    - unidentified bisaccate pollen
      - Abundant and diverse in all samples
  - Family TAXODIACEAE
    - *Glyptostrobus* sp.
      - Common in all samples
    - *Taxodium* sp.
      - Common in all samples
    - cf. *Sciadopitys* sp.
      - Relatively common in all samples
    - *Perinopollenites* cf. *P. elatoides* Couper 1958
      - Rare, but present in all samples
  - Family CUPRESSACEAE and/or TAXACEAE
    - *Inaperturopollenites* sp.
      - Common in all samples
  - Family PODOCARPACEAE
    - *Podocarpidites* sp.
      - Relatively common in all samples
  - Family CHEIROLEPIDACEAE
    - *Classopollis classoides* (Pflug) Pocock and Jansonius 1961
      - Common in all samples

- CONIFERALES – *Incertae sedis*
  - *Eucommiidites troedssonii* Erdtman 1948
    - Rare, but present in all samples
  - *Schizosporis* sp.
    - Rare, seen only in C-17225, C-17228
  - *?Spheripollenites* sp. (monoporate)
    - Rare, seen only in C-17226

- Division ANTHOPHYTA – *Incertae sedis*
  - *Clavatipollenites* cf. *C. hughesii* Couper 1958
    - Rare, seen only in C-17225.

The pollen form which we have called *?Protopicea* is a very large (400–650 μ in overall length), thin-walled bisaccate grain, with slightly pendant bladders. The central body is indistinct and apparently has a wall comparable in thickness to the bladders. This comparatively fragile form occurs sporadically throughout the samples and, unless special care is exercised in processing, individuals are readily lost or destroyed. It is studied most effectively, after extraction, by preparing single grain mounts (the specimen illustrated on Pl. 10, fig. 11, was prepared in this fashion). *?Protopicea* tends to shrink and contract after being placed in a mounting medium, hence the rather crumpled appearance of this specimen. This form, which apparently has not been described before, needs additional study.

Megaspores

Division LYCOPODOPHYTA
Family SELAGINELLACEAE and/or ISOETACEAE

Bacutriletes cf. *B. onodios* (Harris) n. comb.
Plate 11, figures 1–4

Remarks. As the sculpture elements of *Trilete onodios* Harris 1961 are predominantly baculae and, as it conforms in other respects to the diagnosis of *Bacutriletes* Potonié 1956, *Triletes onodios* is transferred to *Bacutriletes* as follows:

Bacutriletes onodios (Harris) n. comb. Syn: *Triletes onodios* Harris, 1961, p. 53, Fig. 16I to L, Fig. 17A to E; Lower to Upper Deltaic Series of England.

Bacutriletes cf. *B. onodios* differs from *B. onodios* in having triradiate lamellae 10 to 36 microns high as compared with those of *B. onodios* which are 40 to 70 microns high. In other respects, including the range of variation in sculpture shape, and density described by Harris (1961), *B.* cf. *B. onodios* is similar to *B. onodios* from the Middle Jurassic of England.

Erlansonisporites sparassis (Murray) Potonié 1956
Plate 11, figures 5–7

Remarks. The range of variation observed in the population studied agrees with that described by Harris (1961) for *E. sparassis*. *Erlansonisporites sparassis* is known from the Middle Jurassic of England (Murray, 1939; Kendall, 1942; Harris, 1961). In Alberta, this species has been found in the Ellerslie Member of the McMurray Formation (Singh, 1964) and in the Upper Cretaceous part of the Brazeau Formation (Gunther and Hills, 1972).

Minerisporites cf. *M. alius* Batten 1969
Plate 11, figures 8–11

Remarks. *Minerisporites* cf. *M. alius* is comparable to *M. alius* in its total wall thickness [4.2–7.6 μ (Av. 5.8) versus 3–7 μ for *M. alius*]; in having spines developed at the confluence of the muri and on the margins of the zona and triradiate lips (Pl. 11, figs. 8–10; Batten, 1969, Pl. 66, fig. 7); and in having a similar mean width of the zona interradially (51.8 μ versus 50 μ for *M. alius*). However, its mean central body diameter is closer to that of cfB. *M. marginatus* (Dijkstra) Potonié 1956 *in* Batten, 1969 (245 μ versus 284 μ for cfB. *M. marginatus* and 334 μ for *M. alius*) as is the form of its reticulation (Pl. 11, fig. 8) and the diameter of the lumina (4–36 μ versus 4–35 μ in cfB. *M. marginatus* and 7–80 μ in *M. alius*).

Minerisporites cf. *M. alius* is similar also to *M. richardsonii* (Murray) Potonié 1956 but differs in having prominent spines at the confluence of the muri restricted to the distal surface. In *M. richardsonii*, the development of spines is more frequent on the proximal surface (Harris, 1961).

Minerisporites alius has been reported from the ?Valanginian of England (Batten, 1969), cfB. *M. marginatus* from the Hauterivian of England (Batten, 1969), and *M. richardsonii* from the Middle Jurassic of England (Murray, 1939; Harris, 1961). Forms similar to *M.* cf. *M. alius* referred to as *M. marginatus* were reported by Singh (1964, Pl. 24, figs. 5–7) from the Ellerslie Member of the McMurray Formation and from the Grand Rapids Formation, both of probable Albian age (Vagvolgyi and Hills, 1969; Singh, 1971).

Tenellisporites spinatus Peake *in* Hall and Peake, 1968

Plate 11, figures 12–15

Remarks. Most specimens (Pl. 11, figs. 12, 13) closely resemble *T. spinatus*, but some (Pl. 11, figs. 14, 15) have an arcuate ridge, the presence of which is not recorded for *T. spinatus*. Those specimens with an arcuate ridge might better be referred to as cfB. *Thomsonia pseudotenella* (Dijkstra) Madler 1954 *in* Batten, 1969. However, equatorial radial outgrowths were not observed on the specimens; hence, the reluctance to make the above assignment.

Tenellisporites spinatus is known from the Cenomanian of Minnesota (Hall and Peake, 1968) and cfB. *Thomsonia pseudotenella* from the Valanginian of England (Batten, 1969).

Paxillitriletes cf. *P. fairlightensis* (Batten) Hall and Nicolson 1973

Plate 11, figures 16–19

Remarks. Except for a larger size, *Paxillitriletes* cf. *P. fairlightensis* is comparable to *P. fairlightensis* reported from the Berriasian of England by Batten (1969). *Paxillitriletes* cf. *P. fairlightensis* has a spore body diameter of 306 to 430 μ (Av. 348) as compared to 165 to 290 μ (Av. 224) for *P. fairlightensis*.

Division PTEROPHYTA

Family MARSILEACEAE

Arcellites disciformis Miner emend. Ellis and Tschudy 1964

Plate 12, figures 1, 4

Remarks. In North America, there are about 13 known occurrences of *A. disciformis* from strata of Albian age (Ellis and Tschudy, 1964; Singh, 1964, 1971), three from Cenomanian beds (Schemel, 1950; Hall, 1963; Ellis and Tschudy, 1964) and one occurrence from the Patuxent Formation (Ellis and Tschudy, 1964) of Aptian age (Doyle, 1973) or possibly Aptian/Albian age (Wolfe and Pakiser, 1971).

Arcellites incipens Singh 1964

Plate 12, figures 7, 8

Remarks. Although the numerical parameters (*see below*) of the specimens from the Mattagami Formation deviate from those given by Singh for *A. incipens*, their referral to *A. incipens* appears justified based on the close agreement in general morphology, neck shape, and neck length to that of *A. incipens*. The observed differences might be explained by the diagnosis of *A. incipens* being based on only two specimens.

Dimenions:

	Mattagami Fm. (present study*)	Ellerslie Mbr. (Singh, 1964)
Total length (including neck)	330 to 670 (552)	385 to 449
Maximum diameter of body (including reticulation)	210 to 476 (374)	269 to 350
Length of neck (above reticulation)	121 to 300 (213)	128 to 179
Width of reticulum	25 to 50 (33)	40 to 50
Width of muri	5.3 to 16 (8.5)	7 to 10
Length of appendages (including height of muri)	30 to 62 (44)	30 to 40

*The numbers in brackets are average values based on 15 measurements. The data are given in microns.

Arcellites incipens was recorded from the Ellerslie Member of the McMurray Formation by Singh (1964) considered Early Albian in age by Vagvolgyi and Hills (1969).

Incertae sedis

Triletes lanaris Vangerow 1954

Plate 12, figure 5

Remarks. Only one specimen of this species was recovered (sample C-29850). Vangerow (1954) described *T. lanaris* from Senonian strata of Germany.

Triletes sp.

Plate 12, figures 2, 3

Remarks. Several specimens of a large (up to 730 μ), psilate megaspore with laesurae two thirds the length of the spore radius and a wall 7 to 14 μ thick were found. To the present knowledge of the authors, this form of megaspore is not known in strata younger than Early Cretaceous.

Spermatites cf. *S. ellipticus* Miner 1935

Plate 12, figure 6

Remarks. A few specimens similar in shape and "cell" pattern to *S. ellipticus* were recovered. *Spermatites* cf. *S. ellipticus* differs from previously described specimens of *S. ellipticus* by their larger size (900 x 1350 μ as compared with 382–664 x 580–930 μ *in* Miner, 1935 and 300-500 x 810–1200 μ *in* Colin, 1973). The known range of *S. ellipticus* is Cenomanian (Schemel, 1950; Colin, 1973) to Maastrichtian (Binda, 1968; Gunther and Hills, 1972).

Discussion

Age

The first attempt to assign an age to the Mattagami Formation was by Keele (1919) who quoted paleobotanists of the United States Geological Survey as stating that the Mattagami "beds are not younger than Kootenay (Upper Jurassic to Neocomian) and they are not older than Permian." Bell (1928), as previously stated, identified five genera of leaves. He concludes by stating (p. 28), "The age of the deposit as inferred from this assemblage, is considered to be either Upper Jurassic or early Lower Cretaceous, with preference toward the latter ... ." Rouse (1956) considered the Mattagami Formation to be Early Cretaceous; it is indicated on his stratigraphic chart as Neocomian and essentially equivalent to the Kootenay Formation of the Crows Nest Pass area.

Based on the analysis of pollen, miospores, and megaspores, undoubtedly the formation is of Early Cretaceous age. Also, the writers feel that these strata are probably Early Albian, although the evidence is not conclusive because the ranges of the identified species are not sufficiently restricted.

An absence of tricolpate angiosperm pollen indicates a probable pre-Middle Albian age, whereas the presence of schizaceous spores indicates post-Jurassic. The high frequency of schizaceous spores (which here are considered to include *Trilobosporites*) suggests a later Early Cretaceous age. Furthermore, several species are more restricted stratigraphically, and their overlapping ranges tend to confirm a late Early Cretaceous age. To the writers' knowledge, *Chomotriletes fragilis* has been recovered only from Aptian and Albian rocks. *Glyptostrobus* has not been found, as either megafossils or pollen, in rocks older than Albian. Also significant is the probable presence of *Spheripollenites subgranulatus* which is not known above the Middle Albian. *Clavatipollenites hughesii* has a range that appears open to some controversy in the literature (*see* Doyle, 1969, 1973; Muller, 1970), but, apparently, does not occur above the lowest Cenomanian. Therefore, the evidence of pollen and miospores suggests an age probably not younger than Early Albian, nor older than Aptian.

With respect to the megaspores, the finding of species (*Spermatites* cf. *S. ellipticus*, *Triletes lanaris*, and *Tenellisporites spinatus*) known only from the Upper Cretaceous, together with morphotypes known previously from the Middle Jurassic (*Bacutriletes* cf. *B. onodios*) and Neocomian (*Minerisporites* cf. *M. alius* and specimens similar to cfB. *Thomsonia pseudotenella*), indicates an age at least as young as late Early Cretaceous. The absence of species assignable to *Costatheca* Hall 1967, *Balmeisporites* Cookson and Dettmann 1958, *Molaspora* Schemel 1953, and *Ariadnaesporites* Potonié 1956 suggests a pre-Cenomanian age. Abundant *Arcellites disciformis* in association with *A. incipens* strongly suggests a post-Albian age. Therefore, the combined evidence from pollen, miospores, and megaspores indicates a probable Early Albian age although the possibility of early Middle Albian or Aptian age is not completely excluded.

Distribution of the Palynomorphs

In general, the species composition of the microfloras remains the same throughout the Mattagami Formation; only the proportions and relative abundance varies. The per cent frequency distribution of the megaspores, based on data compiled from all the samples examined, is shown on the bottom line of Textfigure 26. The dominant forms are seen to be species of *Bacutriletes*, *Arcellites*, *Erlansonisporites*, and *Minerisporites*, listed in descending order of relative abundance.

The lithologic sequence in boreholes 68-38, 68-39, and 68-42 consists of a basal shale (unit 1[1]), a lower (unit 2) and an upper (unit 4) of lignite coal separated by shale and sandstone (unit 3), and an upper, dominantly shale unit (unit 5) (L.L. Price, pers. com.). The absolute abundance of megaspores for each borehole is indicated on Textfigure 25. The two samples available from unit 1 yielded 105 megaspores; the three samples from unit 2, 128 megaspores; the four samples from unit 3, 30 megaspores; the four samples from unit 4, 37 megaspores; and the five samples from unit 5, 38 megaspores. Hence, units 1 and 2 are characterized by an average sample yield of 47 megaspores compared with an average sample yield in units 3 to 5 of 8 megaspores.

The relative abundance of the megaspore species within these five units is shown in Textfigure 26. The per cent frequency diagrams for each unit are based on combined data from boreholes 68-38, 68-39, and 68-42 (samples available for units 3 to 5 only in borehole 68-38). The thicknesses of the units given in Textfigure 26 are averages of the thickness of each unit in boreholes 68-39 and 68-42 based on information supplied by L.L. Price (pers. com.). As shown on Textfigure 26, unit 1 is identifiable by the dominance of *Minerisporites* and *Arcellites;* unit 2 by the dominance of *Arcellites* and *Bacutriletes;* units 3 and 4 by the dominance of *Erlansonisporites;* and unit 5 by the dominance of *Minerisporites* and *Erlansonisporites*.

A definite correlation between the lower lignite unit in the boreholes listed above and the samples from the lignite stockpile adjoining the Onakawana pit can be made based on the similarity in the megaspore profile from the stockpile samples (Textfig. 25, 2nd to bottom line) and the lower lignite unit in the boreholes.

Counts from borehole 68-43 were not included in the borehole profiles shown in Textfigure 26. The seven samples processed from this borehole yielded a total population of 57 megaspores. Of these, 40 per cent were *Erlansonisporites*, 16 per cent *Bacutriletes*, 12 per cent *Paxillitriletes*, 12 per cent *Triletes*, 11 per cent *Minerisporites*, 5 per cent *Arcellites*, and 4 per cent *Spermatites*. Most of the *Bacutriletes* (5 specimens) were recovered from the lower 10 feet (3 m) of shale in the borehole and most of the *Minerisporites* (5 specimens) in the uppermost shale [the 75- to 100-foot (22.8-30.5 m) shale interval]. Except for the somewhat higher percentage of *Bacutriletes*, the total distribution matches that of units 3 to 5 in the other three boreholes. This is anomalous in that borehole 68-43 encompasses two lignite horizons separated by a shale unit. Unless the samples from the lower part of borehole 68-43 were composed mainly of cavings, one would suspect that the lower lignite unit in borehole 68-43 is not correlative with the lower lignite unit in the other boreholes as evidenced by the near absence of *Arcellites* and the low productivity of all the samples in borehole 68-43.

Paleoecology

Bell (1928) interpreted the environment of deposition of the Mattagami Formation to be "... a conifer swamp characterized by periodic floods of water and deposition

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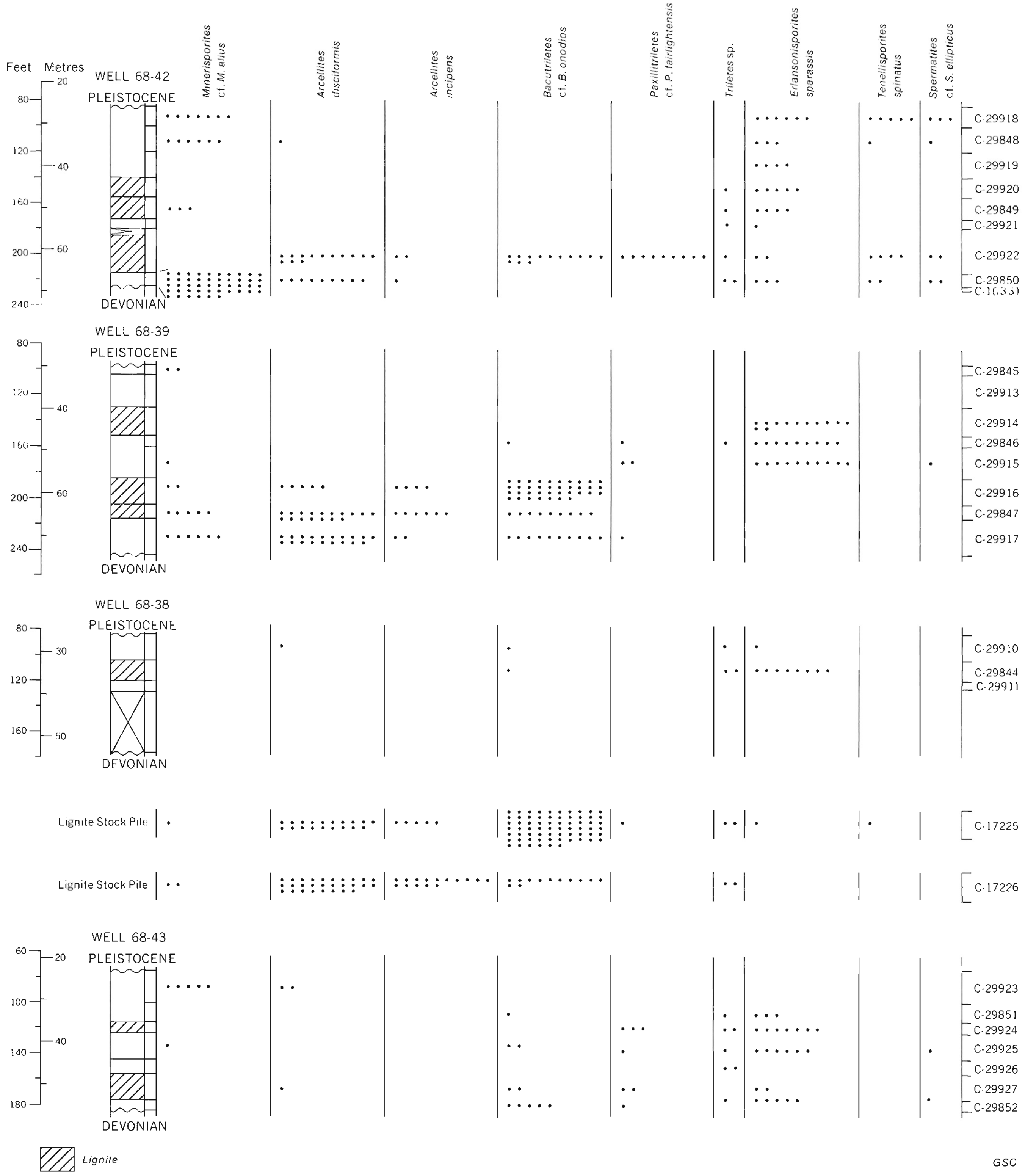
[1] Unit numbers are designated only to provide ease of reference to Textfigure 26.



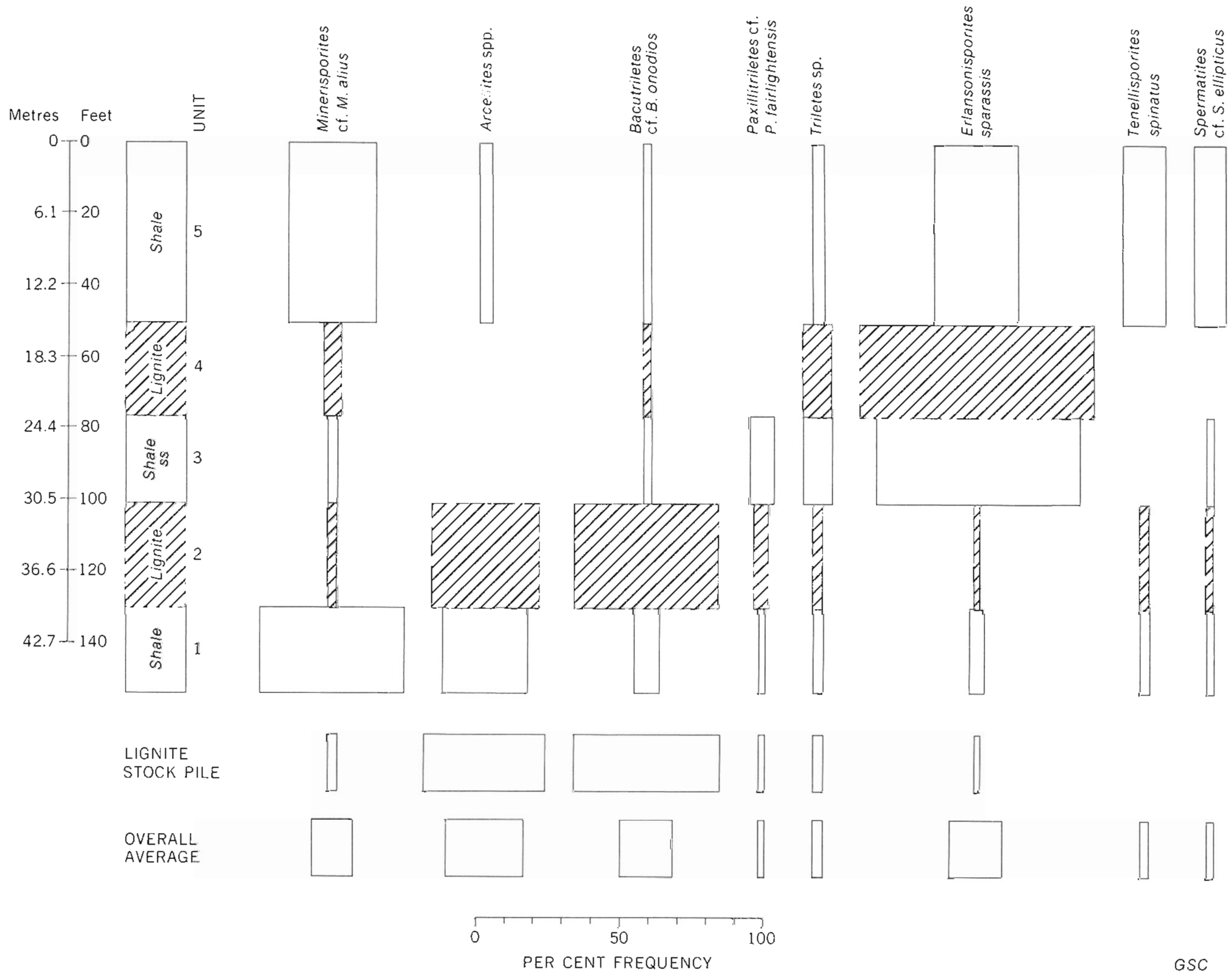
TEXTFIGURE 25. Absolute numbers of megaspores appearing in each borehole and the two stockpile samples.

partially *in situ* after very short transportation into a temporary lake." The present writers concur with this; the limited and generally well preserved pollen, spores, and megaspores suggest that transportation was minimal. The lithology of the formation also suggests a broad lowland of deposition with meandering streams, ephemeral lakes, swamps, and bogs. The principal vegetation was composed of conifers, possibly dominated by the Taxodiaceae, with a rather extensive fern flora. This conifer-fern complex indicates a warm temperate or possibly subtropical climate.

The smaller and lighter microspores and pollen do not show significant variation in either species or frequency from top to bottom of the holes. Therefore, determination of environments of deposition of specific samples is not possible on the basis of the contained palynomorphs. However, megaspores, because of their greater size and weight, are more likely *in situ*. Consequently, as discussed below, they may have more significance for specific environmental interpretations.

In their paper on Cenomanian megaspores from Minnesota, Hall and Peake (1968) found that megaspore assemblages from a coal could be distinguished from those found in lake and stream channel deposits. The coal, interpreted as representing swamp conditions, was found to contain exclusively Pterophyta megaspores belonging to the genera *Arcellites*, *Ariadnaesporites*, and *Molaspora*. The lake and stream deposits contained a more diverse assemblage including megaspores referable to the Lycopodophyta and Pterophyta (Hydropterales). Hall and Peake (ibid.) considered the lycopods to represent, in general, upland plants whereas the Pterophyta megaspores were considered to represent aquatic plants.

Thus, judging by the environment in which occur the extant representatives of the heterosporous ferns, it seems probable that the presence of fossil heterosporous ferns would indicate a paleoenvironment in which either open bodies of water or an extremely high water table existed (swamp, marsh, or lake). Hence, it is likely that unit 1 (Textfig. 26) represents lake deposits and unit 2 marsh and swamp deposits. If it is assumed that the abundant *Arcellites* represent high water table conditions then, conversely, the absence of *Arcellites* in units 3 and 4 can be taken to indicate more terrestrial conditions with a lowered water table. Also, the formation of the upper lignite (unit 4) might be visualized



TEXTFIGURE 26. Diagram of frequency distribution of megaspores in the Mattagami Formation.

under conditions similar to the *Sequoia* or Myricaceae–Cyrillaceae moor floral facies of the German Tertiary brown coal (Teichmüller and Teichmüller, 1968, p. 359). This is opposed to a *Nyssa–Taxodium* swamp or Limnotelmatic grass marsh floral facies (Teichmüller and Teichmüller, 1968, p. 369) which may represent conditions similar to those that existed during the deposition of the lower lignite (unit 2). Unit 5 is thought to represent a return to wetter conditions intermediate between those of unit 1 and unit 3.

The foregoing discussion implies that plants bearing *Minerisporites* cf. *M. alius* and possibly *Tenellisporites spinatus* were adapted to a lacustrine environment; *Bacutriletes* cf. *B. onodios* to a swamp-marsh environment with a high water table; and *Erlansonisporites* and possible *Triletes* sp. to an environment with a lowered water table and, hence, more terrestrial. Thus, species referable to the Lycopodophyta (Selaginellaceae and/or Isoetaceae) are considered to occupy a range of habitats as do extant species of this group. The results of this study support the interpretation of Hall and Peake in which *Tenellisporites spinatus* is represented as an aquatic to semi-aquatic plant. Inherent to the preceding discussion is the assumption that the plants bearing the megaspores were indigenous to the flora which existed during the deposition of the various units rather than occupying an "upland area" (Hall and Peake, 1968), removed from the area of deposition.

Summary

1. The Mattagami Formation is considered to be of late Early Cretaceous and, most probably, Early Albian age, and is, therefore, correlative with the Mannville and Blairmore Groups of western Canada rather than with the Kootenay Formation.
2. If the suggested paleoenvironments for the upper and lower lignite units (excluding those in borehole 68-43) are valid, then it is predictable that differences exist in the petrography of the upper and lower lignite units.
3. Based on the relative abundance of megaspores, it appears possible to identify the separate lignite units. This knowledge might be applied during any future evaluation of the lignite reserves.

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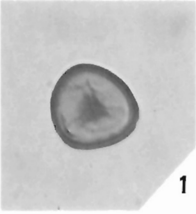
PLATE 9

Miospores

(all figures x500)

Figure 1.	*Stereisporites antiquasporites* (Wilson and Webster) Dettmann 1963; GSC 41585 from GSC loc. C-17233.	(Page 56)
Figure 2.	*Cingutriletes clavus* (Balme) Dettmann 1963; GSC 41586 from GSC loc. C-17231.	(Page 56)
Figure 3.	*Lycopodiumsporites* sp.; GSC 41587 from GSC loc. C-17231.	(Page 56)
Figure 4.	*Sestrosporites pseudoalveolatus* (Couper) Dettmann 1963; GSC 41588 from GSC loc. C-17275.	(Page 56)
Figure 5.	*Laevigatosporites* sp.; GSC 41589 from GSC loc. C-29916.	(Page 56)
Figure 6.	*Osmundacidites wellmanii* Couper 1953; GSC 41590 from GSC loc. C-17275.	(Page 56)
Figure 7.	*Baculatisporites comaumensis* (Cookson) Potonié 1956; GSC 41591 from GSC loc. C-17275.	(Page 56)
Figure 8.	*Gleicheniidites senonicus* Ross 1949; GSC 41592 from GSC loc. C-17232.	(Page 56)
Figure 9.	*Kuylisporites lunaris* Cookson and Dettmann 1958; GSC 41593 from GSC loc. C-29911.	(Page 56)
Figure 10.	*Cyathidites minor* Couper 1953; GSC 41594 from GSC loc. C-29920.	(Page 56)
Figure 11.	*Cicatricosisporites* sp.; GSC 41595 from GSC loc. C-17226.	(Page 56)
Figure 12.	*Cicatricosisporites* sp.; GSC 41596 from GSC loc. C-29914.	(Page 56)
Figure 13.	*Appendicisporites* sp.; GSC 41597 from GSC loc. C-29910.	(Page 56)
Figure 14.	*Trilobosporites apiverrucatus* Couper 1958; GSC 41598 from GSC loc. C-17231.	(Page 56)
Figure 15.	*Trilobosporites apiverrucatus* Couper 1958; GSC 41599 from GSC loc. C-29916.	(Page 56)
Figure 16.	*Lygodium* cf. *L. reticulosporites* Rouse 1962; GSC 41600 from GSC loc. C-29913.	(Page 56)
Figure 17.	*Chomotriletes fragilis* Pocock 1962; GSC 41601 from GSC loc. C-16231.	(Page 56)
Figure 18.	*Converrucosisporites* sp.; GSC 41602 from GSC loc. C-29916.	(Page 56)
Figure 19.	*Densoisporites* sp.; GSC 41603 from GSC loc. C-29913.	(Page 56)
Figure 20.	*Cycadopites* cf. *C. scabratus* Stanley 1965; GSC 41604 from GSC loc. C-17230.	(Page 56)
Figure 21.	*Vitreisporites pallidus* (Reissinger) Nilsson 1958; GSC 41605 from GSC loc. C-17275.	(Page 57)
Figure 22.	*Vitreisporites pallidus* (Reissinger) Nilsson 1958; GSC 41606 from GSC loc. C-29910.	(Page 57)
Figure 23.	*Tsugaepollenites mesozoicus* Couper 1958; GSC 41607 from GSC loc. C-29921.	(Page 57)
Figure 24.	*Glyptostrobus* sp.; GSC 41608 from GSC loc. C-29917.	(Page 57)
Figure 25.	*Sciadopitys* sp.; GSC 41609 from GSC loc. C-17231.	(Page 57)
Figure 26.	*Classopollis classoides* (Pflug) Pocock and Jansonius 1961; GSC 41610 from GSC loc. C-29921.	(Page 57)
Figure 27.	*Eucommiidites troedssonii* Erdtman 1948; GSC 41611 from GSC loc. C-29913.	(Page 57)
Figure 28.	*Eucommiidites troedssonii* Erdtman 1948; GSC 41612 from GSC loc. C-29913.	(Page 57)
Figure 29.	*?Spheripollenites* sp.; GSC 41613 from GSC loc. C-17226	(Page 57)

PLATE 9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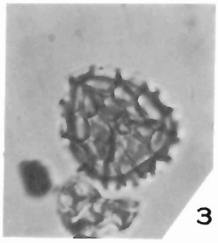
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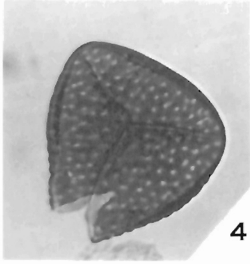
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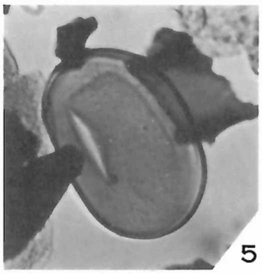
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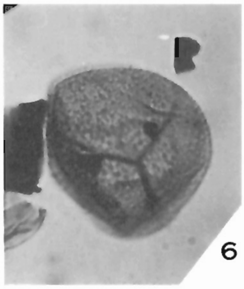
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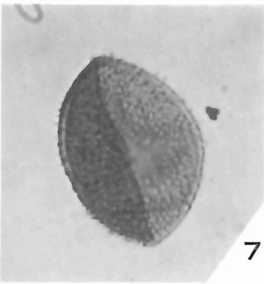
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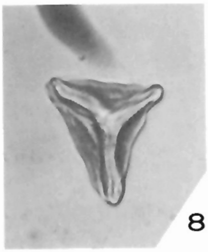
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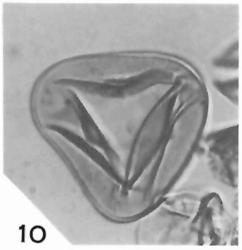
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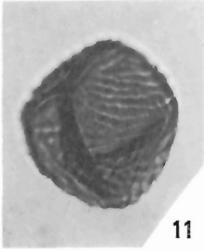
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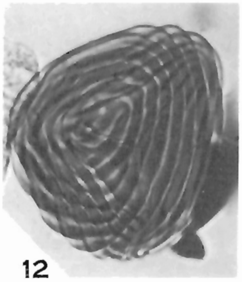
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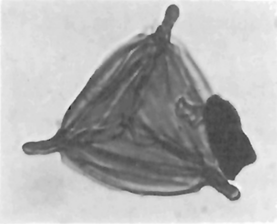
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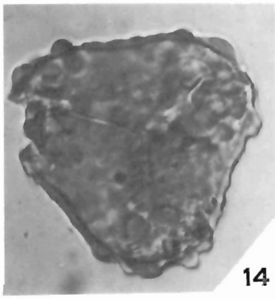
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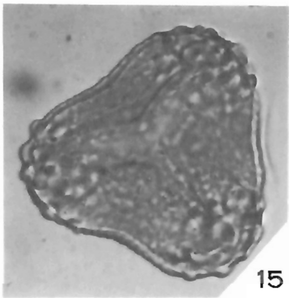
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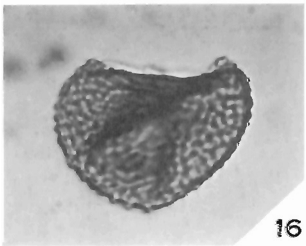
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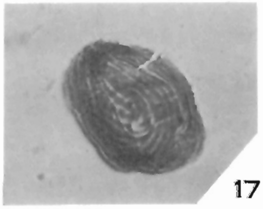
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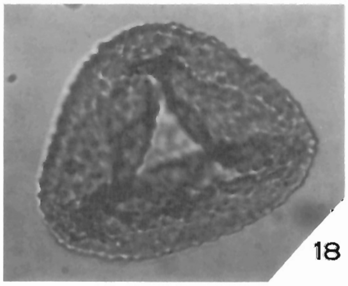
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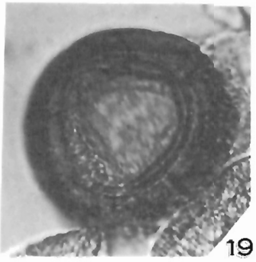
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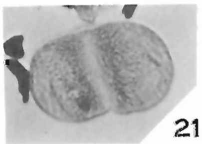
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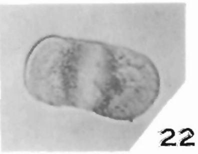
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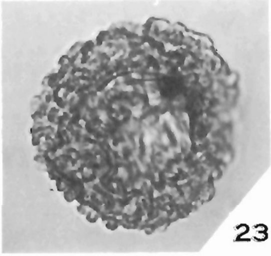
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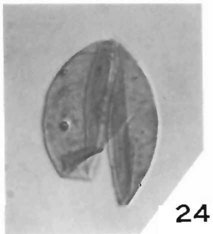
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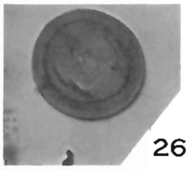
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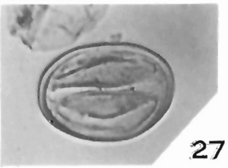
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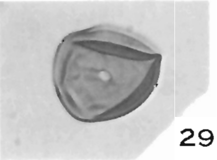
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Plate 10

Miospores

(All figures x500, except where indicated)

Figure 1. *Perinopollenites* cf. *P. elatoides* Couper 1958; GSC 41614 from GSC loc. C-29917. (Page 57)

Figure 2. *Inaperturopollenites* sp.; GSC 41615 from GSC loc. C-17228. (Page 57)

Figure 3. *Podocarpidites* sp.; GSC 41616 from GSC loc. C-17225. (Page 57)

Figure 4. *Podocarpidites* sp.; GSC 41617 from GSC loc. C-17226. (Page 57)

Figure 5. *Schizosporis* sp.; GSC 41618 from GSC loc. C-17228. (Page 57)

Figure 6. *Clavatipollenites* cf. *C. hughesii* Couper 1958; GSC 41619 from GSC loc. C-17225. (Page 57)

Figure 7. *Laricoidites* cf. *L. magnus* (Potonié) Potonié, Thomson, Thiergart 1962; GSC 41620 from GSC loc. C-29848; x600. (Page 57)

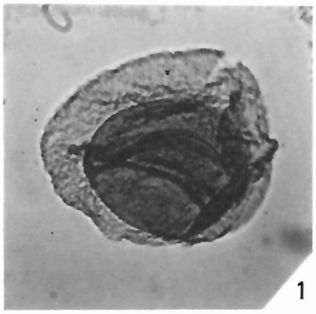
Figure 8. *Alisporites* sp.; GSC 41621 from GSC loc. C-29848; x600. (Page 57)

Figure 9. cf. *Phyllocladidites* sp.; GSC 41622 from GSC loc. C-17275. (Page 57)

Figure 10. *Alisporites* cf. *A. bilateralis* Rouse 1959; GSC 41623 from GSC loc. C-17231. (Page 57)

Figure 11. *?Protopicea* sp.; GSC 41624 from GSC loc. C-29844; x175. (Page 57)

PLATE 10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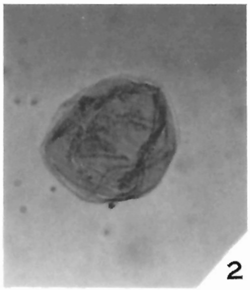
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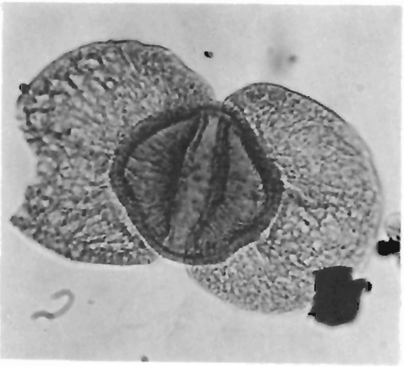
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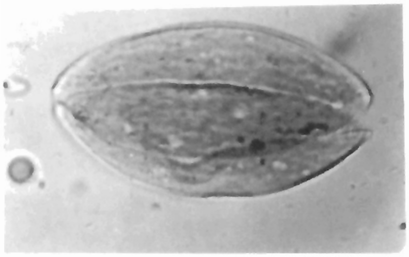
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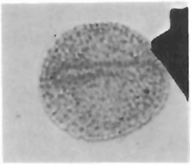
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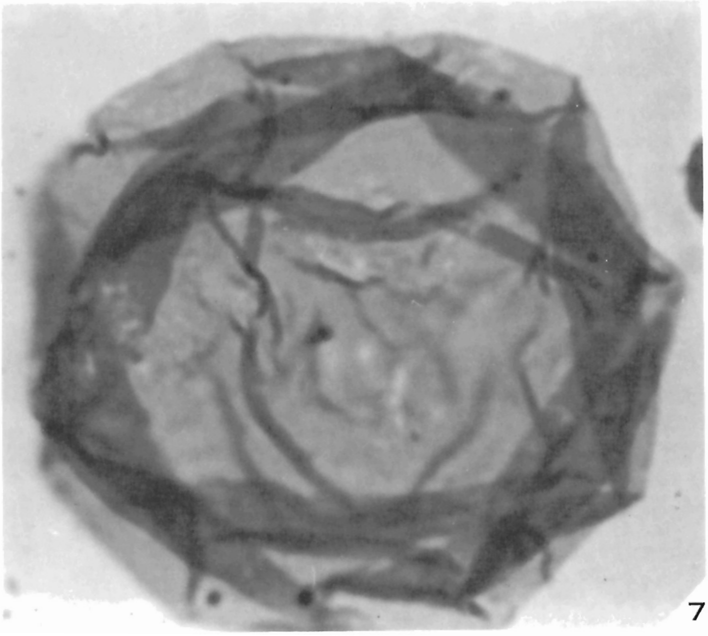
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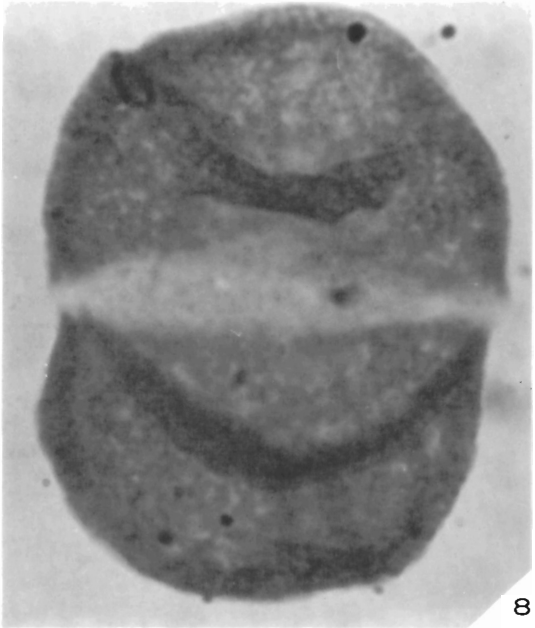
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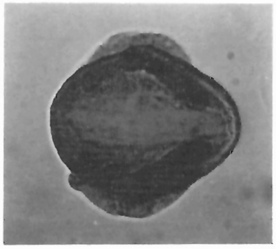
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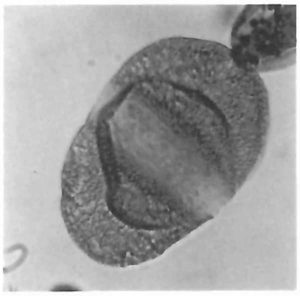
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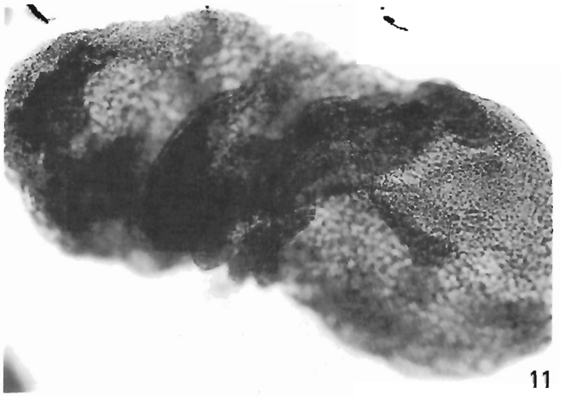
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PLATE 11

Megaspores

(All figures x100; micrographs bright field unless otherwise indicated)

Bacutriletes cf. *B. onodios* (Harris) (Page 57)

Figures 1–4. Figures 1 and 2 incident light micrographs of unoxidized specimens showing reduced proximal ornament and figure 4 is an interference contrast micrograph. Figures 1–3, GSC 41625–41627 from GSC loc. C-17225; figure 4, GSC 41628 from GSC loc. C-29852.

Erlansonisporites sparassis (Murray) Potonié (Page 57)

Figures 5–7. Figure 5 incident light micrograph of proximal surface of unoxidized specimen; GSC 41629 from GSC loc. C-29844; figures 6, 7, GSC 41630, 41631, both from GSC loc. C-29914.

Minerisporites cf. *M. alius* Batten (Page 57)

Figures 8–11. Figures 8–10 interference contrast micrographs; figure 11 incident light micrograph of proximal surface. Figures 8–11, GSC 41632-41635, all from GSC loc. C-29850.

Tenellisporites spinatus Peake (Page 58)

Figures 12–15. Figure 15 incident light micrograph in equatorial view. Figure 12, GSC 41636 from GSC loc. C-29850; figure 13, GSC 41637 from GSC loc. C-29922; figure 14, GSC 41638 from GSC loc. C-29918; figure 15, GSC 41639 from GSC loc. C-29848.

Paxillitriletes cf. *P. fairlightensis* (Batten) Hall and Nicholson (Page 58)

Figures 16–19. Figure 16 incident light micrograph in equatorial view. Figure 16, GSC 41640 from GSC loc. C-29847; figures 17, 18, GSC 41641, 41642, both from GSC loc. C-29922; figure 19, GSC 41643 from GSC loc. C-29915.


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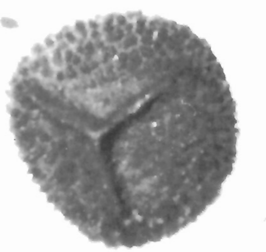
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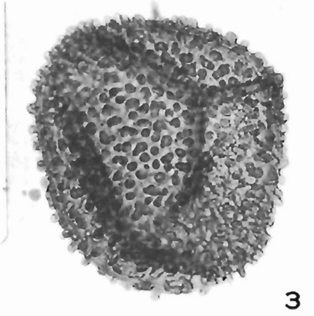
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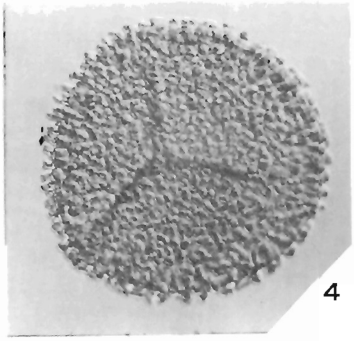
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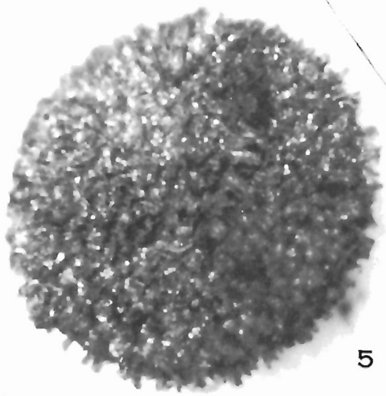
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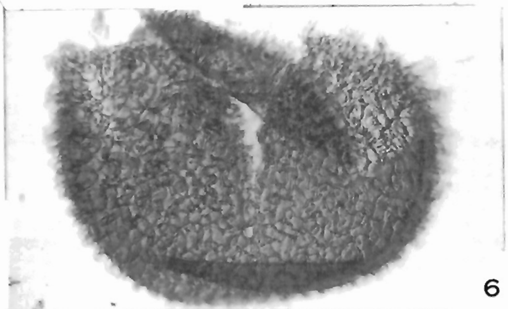
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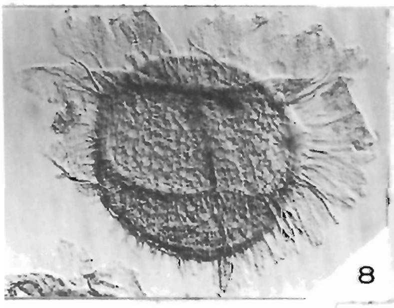
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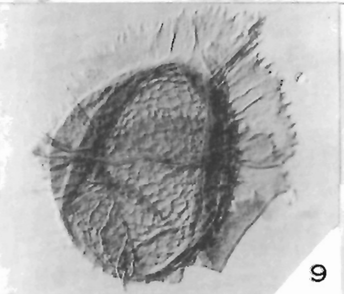
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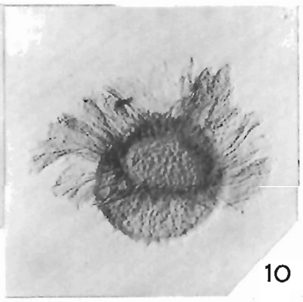
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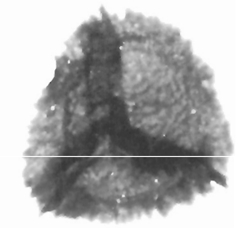
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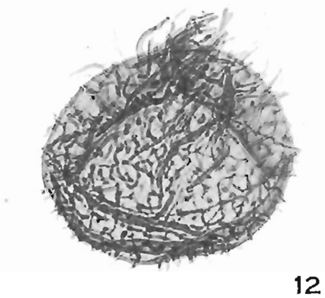
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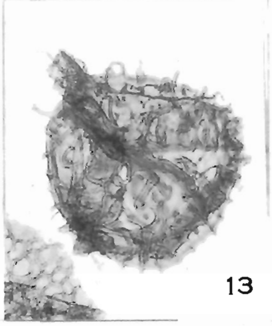
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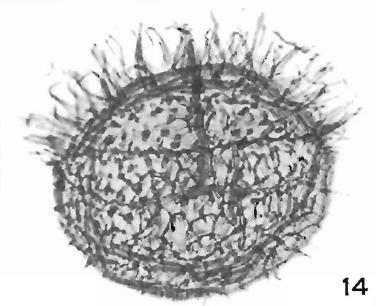
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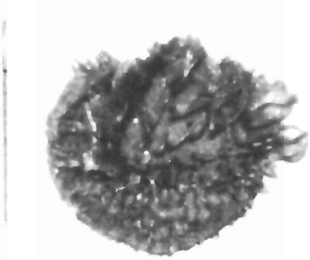
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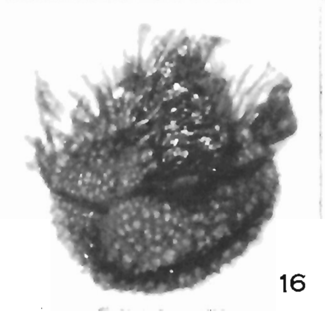
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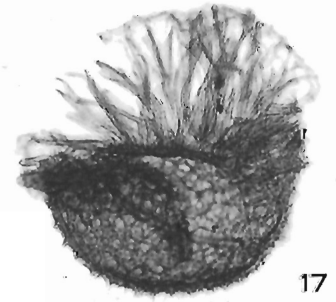
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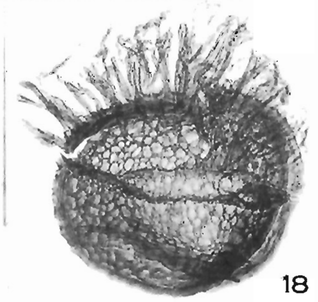
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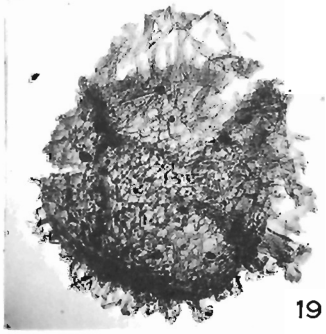
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PLATE 12

Megaspores

(All figures x100; micrographs bright field unless otherwise indicated)

Arcellites disciformis Miner (Page 58)

Figures 1, 4. Figure 4 incident light micrograph in equatorial view. Figures 1, 4, GSC 41644, 41645, both from GSC loc. C-17225.

Triletes sp. (Page 58)

Figures 2, 3. Figure 2 incident light micrograph in proximal view. Figure 2, GSC 41646 from GSC loc. C-29926; figure 3, GSC 41647 from GSC loc. C-29911.

Triletes lanaris Vangerow (Page 58)

Figure 5. GSC 41648 from GSC loc. C-29850.

Spermatites cf. *S. ellipticus* Miner (Page 58)

Figure 6. GSC 41649 from GSC loc. C-29850.

Arcellites incipens Singh (Page 58)

Figures 7, 8. Figure 8 incident light micrograph in equatorial view. Figure 7, GSC 41650 from GSC loc. C-17225; figure 8, GSC 41651 from GSC loc. C-29847.


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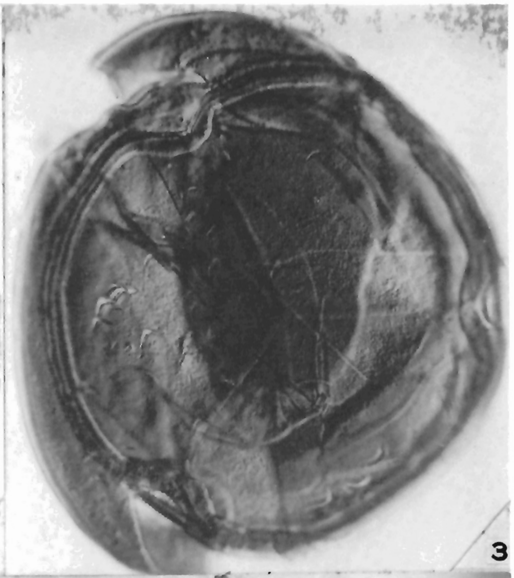
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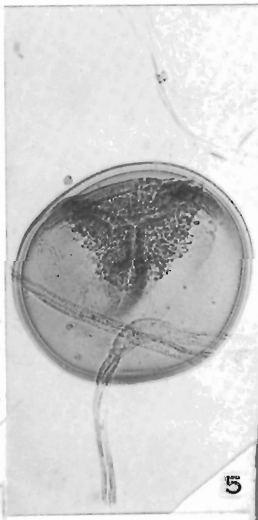
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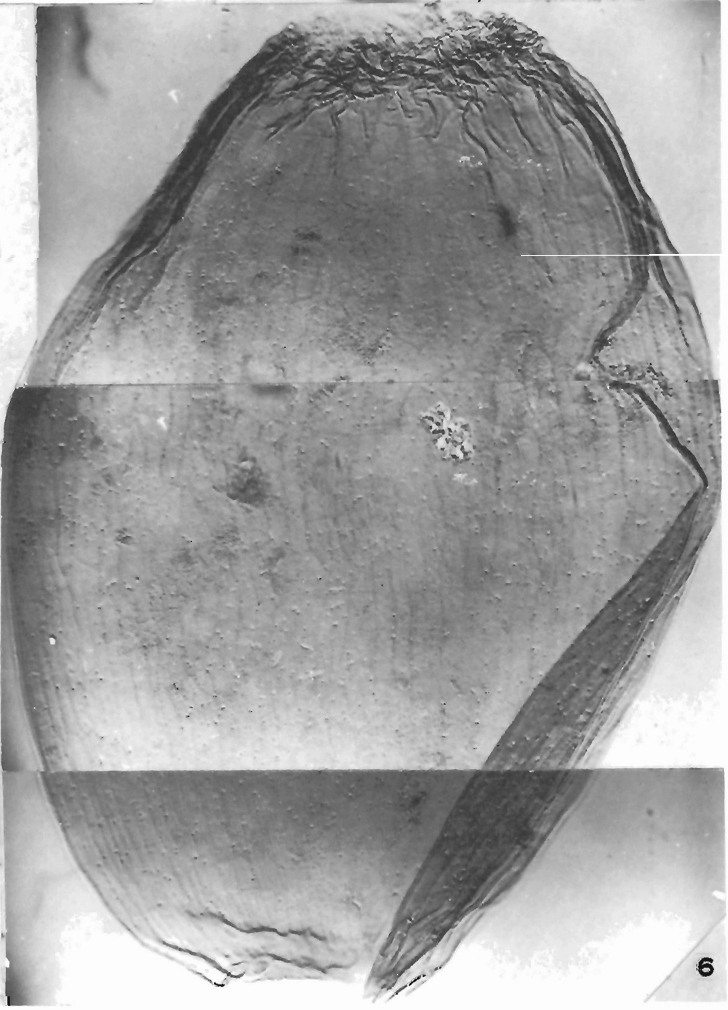
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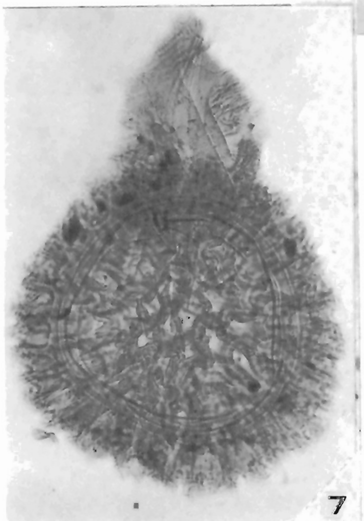
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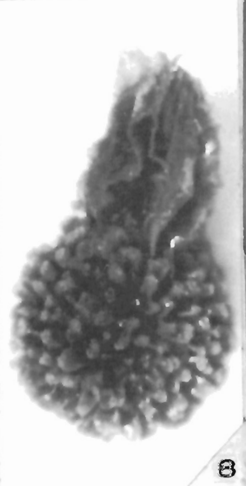
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