REASSESSMENT OF ARENIG AND LLANVIRN AGE (EARLY ORDOVICIAN) BRACHIOPODS FROM ANGLESEY, NORTH-WEST WALES

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ABSTRACT. The distinctness of the Celtic biogeographic province in late Arenig and early Llanvirn time is confirmed by reassessment of its brachiopods from Anglesey. Of the eighteen brachiopod species in the Arenig Treiorwerth Formation, two orthaceans are placed in new monotypic genera: *Treioria chaulioda* sp. nov. and *Ffynnonia costata* (Bates); the four other endemic genera, together with *Orthambonites*, *Productorthis*, *Tritoechia*, and *Rugostrophia*, constitute an assemblage very similar to that found in volcaniclastic rocks of the northern Appalachians which has also been assigned to the Celtic province. The seven brachiopod taxa identified in the Llanvirn Bod Deiniol Formation include Baltic and Scoto-Appalachian forms also found together in these North American rocks. Although geological evidence supports separation of the Celtic province areas from those of the Scoto-Appalachian province by the Iapetus Ocean, there is no similar evidence to indicate a comparable separation between the Celtic province areas and those of the Anglo-French province such as the Shelve district.

THE Celtic brachiopod faunal province in the early part of the Ordovician was identified by Williams (1973, p. 249) based on brachiopods from Anglesey, north-west Wales (Bates 1968), and Tagoat, south-east Ireland (Bates *in* Brenchley *et al.* 1967, p. 388). Investigation of the brachiopods in new collections from Anglesey confirms the special character of these associations and supports their grouping by Williams with brachiopod assemblages in volcaniclastic rocks of the northern Appalachians of North America (Shin Brook Formation, Maine; Summerford Group, Newfoundland; Neuman 1964, 1976). From richly fossiliferous shell beds of the Treiorwerth Formation (upper Arenig) about one thousand brachiopod specimens were identified, classified into eighteen taxa including six endemic genera and four genera (*Orthambonites*, *Productorthis*, *Tritoechia*, and *Rugostrophia*) whose association is the hallmark of the Celtic province. The new collection from the Bod Deiniol Formation (lower Llanvirn) yielded fewer specimens and fewer taxa, none endemic, but constitutes an association that indicates links both with the volcaniclastic rocks of eastern North America and the contemporaneous epicontinental rocks of the Baltic province. The Treiorwerth, Bod Deiniol, and closely related Nantannog Formations form a sedimentary complex on Anglesey that is re-examined here in the light of evidence indicating their deposition in shallow water surrounding an island or group of islands, the Irish Sea horst. Such an interpretation is consistent with the evidence of the peri-insular nature of the Celtic province faunas.

GEOLOGICAL SETTING

The Arenig and Llanvirn brachiopod faunas of Anglesey and south-east Ireland appear to occupy a unique position within the British Caledonides. In both places

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they occur in coarse sandstones that are parts of sequences overlying Precambrian metasedimentary rocks, the Mona Complex of Anglesey, and the Rosslare Complex of Ireland (Crimes and Dhonau 1967). These Precambrian rocks form the earliest expression of a persistent structure, the Irish Sea geanticline of Jones (1938), now known as the Irish Sea horst (e.g. Dewey 1969*b*).

The Mona Complex in Anglesey and its equivalents in south-east Ireland include olistostromes, pillow lavas, and acid volcanic rocks as well as turbidites and fine-grained sedimentary rocks (Shackleton 1969). Folding and metamorphism of the Mona Complex took place in the late Precambrian to early Cambrian to form a metamorphosed basement on the surface of which lie Arvonian acid volcanic rocks of probable early Cambrian age. Dewey (1969*a*) regarded this cycle as having taken place on the north-west margin of a continental plate, the depositional apron of Mona Complex rocks built out to the north-west concurrent with subduction and orogeny due to a south-east-dipping Benioff zone.

There is little evidence for the presence of Cambrian rocks on the Irish Sea horst. The unfossiliferous Trefdraeth Conglomerate and Careg-onen Beds (Greenly 1919; Wood 1969) are possibly of Cambrian age, but they equally well could be early Ordovician. If a Cambrian cover was deposited, it was almost completely stripped off by Arenig time.

The Arenig transgression in Anglesey (Bates 1972, p. 56) took place over a surface of varied relief whose positive areas may be the present-day outcrops of the Mona Complex. Basal quartz sandstone, the Carmel Formation, contains a fauna of low diversity (two brachiopod genera and four trilobite genera) which has similarities with that of the Arenig area (Whittington 1966; Bates 1969) and Shelve (Whittard 1955–1967; Williams 1974).

Succeeding these are the distinctive and closely related Treiorwerth, Nantannog, and Bod Deiniol formations, including beds containing the fossils which are the subject of this paper. These formations are characterized by their local derivation, immaturity, variability, and limited areal distribution.

The Treiorwerth Formation is a suite of massive conglomerates, breccias and sandstones about 1200 m thick. The framework of these rocks is composed of angular to subangular blocks of schist, jasper, quartzite, quartz, and phyllite, all readily matched with rock types in the Mona Complex. The matrix is formed of finer particles of the same materials. The shelly fossils were found near the base of the formation, in well-bedded sandstone and fine-grained conglomerate. These fossils are concentrated in lenses, all the brachiopods are disarticulated, and many of them are broken. Fragments of graptolites identified by Elles as ?*Tetragraptus headi* Hall were also collected from these sandstones (Greenly 1919, p. 442).

The rocks of the Nantannog Formation consist of similar materials but with a blue-grey muddy matrix forming muddy grits, conglomerates, and gritty conglomeratic mudstones, all with shale interbeds. *Didymograptus extensus* and *D. hirundo* were found near the base of the formation, and *D. bifidus* somewhat higher (Bates 1968, pp. 134–135; see text-fig. 1B). The Bod Deiniol is a lens within the Nantannog Formation above the level of the lowest occurrence of *D. bifidus*; it is essentially a recurrence of the Treiorwerth lithology. Its beds also consist of rock fragments derived from the Mona Complex lying in a greenish chloritic matrix; its brachiopods,

widely scattered through a few beds, are disarticulated and commonly abraded and broken.

The Treiorwerth, Nantannog, and Bod Deiniol formations appear to have been derived from a source area of irregular topography, the Irish Sea horst, transported a short distance eastward, and deposited on a sea-floor of widely varying bathymetry. In this area the horst may have been a composite feature whose surface expression was a complex of small islands on which rocks of the Mona Complex were exposed, the relief between them and the surrounding submerged areas maintained by repeated movements on a series of faults (Bates 1974, p. 45).

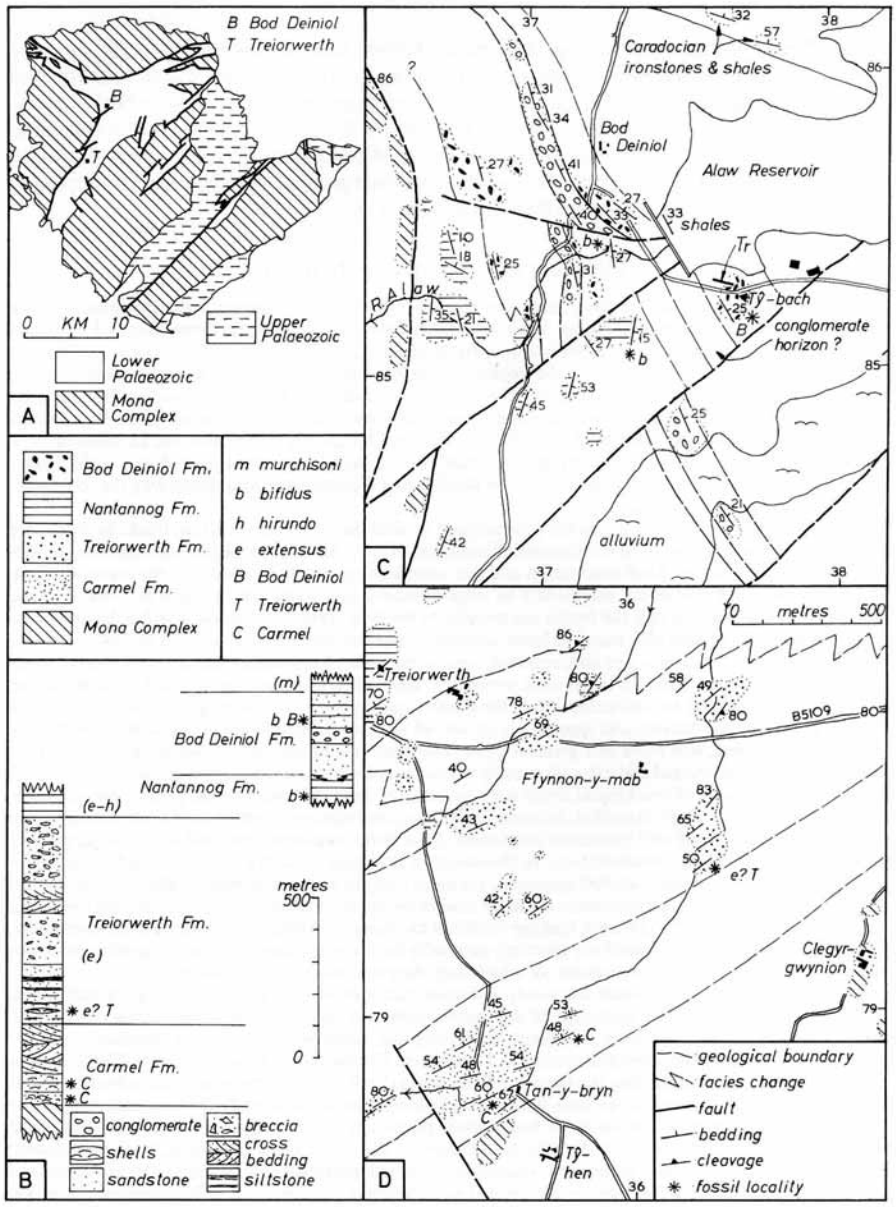
RESTUDY OF THE BRACHIOPODS

Most of the fossils examined for this study were obtained from samples collected by both authors in June 1971, and prepared by Neuman. About 35 kg were taken from the Treiorwerth Formation at Ffynnon-y-mab (text-fig. 1D), the same locality earlier exploited by Greenly (1919, p. 442) and Bates (1968, p. 134). The fossiliferous beds here are confined to the uppermost metre of the 5 m exposed. Bates has continued the collecting and preparation of brachiopods from this locality, and some better-preserved specimens of the less common taxa of brachiopods were obtained from this work. The fossiliferous bed in the Bod Deiniol Formation previously accessible to Bates (1968, p. 135) in a temporary trench was not exposed in 1971. Search of outcrops in that vicinity (text-fig. 1C) yielded no fossils, but examination of blocks at the base of Tŷ-bach cottage, now abandoned, yielded one of Bod Deiniol lithology weighing about 8 kg that contained brachiopods.

Fossils in the Treiorwerth samples are concentrated in shell beds as much as 10 cm thick. In these shell beds brachiopods are by far the most abundant fossils; less than 5% are of other phyla, principally bryozoans and pelmatozoan ossicles. Shell orientation and size sorting are poor; shells about 10 mm across are most abundant, but small specimens are present in large numbers, and some are as much as twice as large. Similarly, although about half the fossils are parallel to bedding surfaces, an equal number lie at various angles to bedding. Fossils also occur in lesser concentrations outside the shell beds, in better-sorted thin zones where small specimens are concentrated, and some isolated specimens occur in relatively barren sandstone. Most of the samples taken were weathered, decalcified and rusty brown, and in such rock all fossils (with the rare and notable exception of the siliceous preservation of a single gastropod specimen and four specimens of one brachiopod species) are preserved as natural internal and external moulds. Part of the sample, however, was fresh and greenish-grey. This rock was decalcified in hydrochloric acid in the laboratory, yielding internal and external moulds whose surfaces are somewhat greener than the surrounding matrix. Thousands of brachiopod shells were included in these samples, of which about one thousand specimens were individually identified. Selection of the identified specimens introduced some bias in favour of the more complete and well-preserved individuals, those with counterpart internal and external moulds, and specimens of the less abundant taxa. In the course of breaking up such a sample for individual specimens the more robust, thicker-shelled specimens are more likely to be retained than smaller, thinner-shelled ones, and the outlines of such specimens are more readily preserved. The smaller, thinner-shelled specimens are more easily broken in this process, making it difficult to estimate the effect of abrasion on the assemblage. Thus, firm indications of abrasion are relatively rare with the notable exception of many specimens of one common species, *Rhynchorthis rotundus*, of which only the posterior parts are preserved.

In the Bod Deiniol block, fossils are widely and more evenly disseminated. Almost all are brachiopods, 10–15 mm across, with a few fragments of bryozoan zoaria and disarticulated pelmatozoan ossicles. All the brachiopods are disarticulated, and many are incomplete, apparently the result of abrasion.

The list of brachiopods identified from the Treiorwerth Formation at Ffynnon-y-mab (Table 1) now includes eighteen taxa rather than the twelve cited by Bates (1968, p. 134). The new list includes taxonomic revisions, re-identifications, and six taxa not previously seen. The revisions include: 1, identification as an unnamed species of *Orthambonites* those brachiopods previously listed as *Lenorthis proava* (Salter); 2, an unnamed species of *Productorthis* for those included in *Panderina lamellosa* Bates, here abandoned; 3, identification as *Tritoechia pyramidalis* (Bates) brachiopods previously identified as *Tritoechia* sp. and *Antigonambonites pyramidalis*. The species erected as *Pleurorthis costatus* Bates is here rejected from that


B Bod Deiniol
T Treiorwerth
0 KM 10
Upper Palaeozoic
Lower Palaeozoic
Mona Complex
A
Bod Deiniol Fm.
Nantannog Fm.
Treiorwerth Fm.
Carmel Fm.
Mona Complex
m murchisoni
b bifidus
h hirundo
e extensus
B Bod Deiniol
T Treiorwerth
C Carmel
(m)
b B*
Bod Deiniol Fm.
Nantannog Fm.
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metres
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Carmel Fm.
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* C
0
conglomerate
shells
sandstone
breccia
cross bedding
siltstone
B
Caradocian ironstones & shales
Bod Deiniol
Alaw Reservoir
shales
Tr
Ty-bach
B
conglomerate horizon ?
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e? T
Clegyr-gwynion
* C
Tan-y-bryn
Tŷ-hen
D
geological boundary
facies change
fault
bedding
cleavage
* fossil locality

genus and assigned to a new genus, *Ffynnonia*. Only one of the six species newly identified, *Treioria chaulioda* is formally named and placed in a new genus, and five others are identified with open nomenclature at taxonomic levels ranging from genus to order.

TABLE 1. List of brachiopods identified from the Treiorwerth Formation at Ffynnon-y-mab, including the number of specimens identified from samples prepared for this study.

BATES 1968	NEUMAN and BATES, this paper	Dorsal valves	Ventral valves	Total
INARTICULATES				
	Petrocrania? sp.	1	—	1
	craniids indet.	4	—	4
	kutorginidaid indet.	1	3	4
ORTHIDS				
Hesperonomiella(?) sp.	*Hesperonomiella* sp.	3	5	8
Monorthis typis	*Monorthis typis*	15	11	26
	Treioria chaulioda	12	28	40
Lenorthis proava	*Orthambonites* sp.	38	103	141
Panderina lamellosa	*Productorthis* sp.	31	29	60
Rhynchorthis rotundus	*Rhynchorthis rotundus*	61	68	129
Pleurorthis costatus	*Ffynnonia costata*	105	112	217
Skenidioides sp. (1)	*Skenidioides* sp. (1)	16	23	39
	Paurorthis? sp.	30	26	56
CLITAMBONITID				
Antigonambonites pyramidalis *Tritoechia* sp.	*Tritoechia pyramidalis*	45	49	94
PLECTAMBONITID				
Reinversella monensis	*Reinversella monensis*	35	18	53
PORAMBONITIDS				
Porambonites (s.s.) sp. (part)	*Rugostrophia* sp.	10	6	16
Porambonites (s.s.) sp. (part)	porambonitid indet.	1	—	1
SYNTROPHIDS				
Rectotrophia globularis	*Rectotrophia globularis*	21	25	46
	Diaphelasma? sp.	2	—	2

Bryozoans are the most common fossils after brachiopods in the Treiorwerth samples. Decalcification rendered most specimens unamenable to thin-section study normal for bryozoan identification, and for these only the growth form and filling of zoecia can be seen. The most numerous are cylindrical, 2–3 mm in diameter, as much as 15 mm long, some of which branch. Other forms are hemispherical, commonly 15 mm in diameter at the base, and still others appear to be thin encrustations over unidentified objects of a wide range of sizes and shapes. In thin sections fragments of both cylindrical and hemispherical forms have the characteristics of generalized trepostomes according to O. L. Karklins (pers. comm. 1976). He also found a rare form with anastomosing slender branches resembling those of the phylloporinids.

TEXT-FIG. 1. A, simplified geological map of Anglesey showing location of Bod Deiniol and Treiorwerth. B, columnar sections showing relative positions of formations discussed in text and levels at which fossils have been found. C, D, geological maps of Bod Deiniol and Treiorwerth areas, respectively; note explanation of both maps to left; on C, in the vicinity of Tŷ-bach cottage, the short, heavy line between the road and the shore of Alaw Reservoir, labelled Tr, marks the site of the temporary trench from which Bates collected fossils from the Bod Deiniol Formation; both maps at the same scale; National Grid Reference ticks shown along borders.

Among the minor components of the Treiorwerth assemblage are pelmatozoan plates, including basal plates belonging to *Rhipidocystites* or *Batherocystites*, and deltoid plates belonging to *Blastoidocrinus* or *Meristoschisma* according to C. R. C. Paul (pers. comm. 1976). The few trilobite fragments consist of several free cheeks and part of a large cephalon, all too fragmentary for identification, and a single cephalon of an agnostid, probably *Geragnostus*. It should be noted that *Monella perplexa* Bates from the Carmel Formation is considered to be congeneric with *Annamitella*? *borealis* Whittington (Whittington pers. comm. 1969, cited by Neuman 1972) and *A.*? *insulana* Dean (Dean 1973, p. 21).

TABLE 2. List of brachiopods identified from the Bod Deiniol Formation; Bates's samples obtained from outcrop in temporary excavation indicated in text-fig. 1c; samples for this study prepared from block taken from base of Tŷ-bach cottage; number of specimens identified is based on material from this block.

BATES 1968	NEUMAN and BATES, this paper	Dorsal valves	Ventral valves	Total
ORTHIDS				
Lenorthis sp.	*Orthambonites* sp.	12	18	30
Panderina(?) sp.	*Productorthis* sp.	4	32	36
Paurorthis(?) sp.				
	Platystrophia? sp.	8	5	13
CLITAMONITID				
Apomatella sp.	*Atelelasma* sp.	2	5	7
GONAMBONITID				
	Antigonambonites sp.	1	1	2
PLECTAMBONITIDS				
	Taffia? sp.	—	6	6
Ahtiella concava	*Ahtiella concava*	37	31	68

The revised list of brachiopods from the Bod Deiniol Formation (Table 2), based on about one-fifth the number of specimens that were obtained from the Treiorwerth Formation, now includes seven taxa rather than the five cited by Bates (1968, p. 135). In addition to re-identifications, the list is altered by the addition of *Platystrophia*? sp., *Antigonambonites* sp., and *Taffia*? sp. The additional specimens of *Ahtiella concava* Bates confirm its generic assignment. Minor components include a few scattered pelmatozoan plates, mostly stem plates, and, rarely, cylindrical bryozoan zoaria.

TAPHONOMY

Comparison of the relative abundance of brachiopod specimens in the Anglesey formations with those of the Summerford Group in Newfoundland (Neuman 1976, p. 12), together with consideration of the rocks in which they occur, indicates that despite the similarity of their genera, the assemblages in the two places represent greatly different habitats. All indications are that the Treiorwerth and Bod Deiniol fossils are death assemblages, and perhaps represent a composite of brachiopods and other organisms that lived in different rocky habitats around the island or islands from which the sediment in which they are entombed was derived. In the Treiorwerth assemblage more than half the brachiopods identified belong to the three most abundant taxa. Two of the most abundant species, *Ffynnonia costata* and *Rhynchorthis rotundus*, include specimens of a wide range of sizes and nearly equal numbers of dorsal and ventral valves. Both are represented by many well-preserved specimens, but some specimens of *Rhynchorthis* are significantly abraded. These species must have been numerically dominant near their place of burial. The species of *Orthambonites* of this assemblage, second in abundance, is represented by nearly three times as many ventral valves as dorsals; although specimens include a wide size range, only a few of the large individuals seem to have complete anterior outlines, suggesting that the specimens were derived from a large population that lived at a greater distance from their burial site than *Ffynnonia* and *Rhynchorthis*. The *Orthambonites* is anomalous among the more common brachiopod species in the disparate number of opposite

valves. All but the rarest of the others are represented by nearly equal numbers of opposite valves, and none of them showed notable evidence of abrasion. All but *Skenidioides* are significantly larger than the average size of the rock particles. It is likely, therefore, that these species lived near the place they were buried, and that their relative abundances were similar to those recorded here. Indications of significant transport or redeposition by such agencies as turbidity currents are lacking. The shell beds are more likely to have been near-shore lag concentrates and thus a reasonable sample of the brachiopod population living nearby.

The Bod Deiniol Formation brachiopods, though fewer in number and taxa than those of the Treiorwerth Formation, more widely disseminated through the available sample, and more abraded, show a similar numerical dominance of the most abundant species.

These data on relative abundance of taxa cannot be interpreted unequivocally. Although numerical dominance of a relatively few species is considered to be characteristic of cold waters, local environmental conditions may have the same effect for any one sampling site. For example, a wide range of relative abundances was seen at the four penecontemporaneous localities yielding brachiopods from volcaniclastic rocks of the Summerford Group (Neuman 1976, p. 12). Here, in the most diversified assemblage that accumulated in quiet, shallow waters, the three most abundant taxa constitute less than one-third of the total assemblage of twenty-six taxa, but at the locality having the least diversified assemblage, and where the effects of currents are evident, more than half the specimens belonged to one of eight taxa.

BIOGEOGRAPHIC INTERPRETATION

The principal conclusion that we derive from this study is that the brachiopod assemblage of the Treiorwerth Formation, the reference assemblage for the Celtic biogeographic province of Williams (1973, p. 249), is like that of the Summerford Group, Newfoundland (Neuman 1976) and related formations in New Brunswick and Maine in the co-occurrence of several genera not known to be associated elsewhere, as well as a high percentage of endemic genera. The smaller number of brachiopod genera of the Bod Deiniol Formation also occur in the Summerford Group. Thus the probability of a Celtic province in the late Arenig and early Llanvirn is reinforced, and the assignment to it of this part of Anglesey together with parts of central Newfoundland, New Brunswick, and Maine (Neuman 1976) is confirmed.

Of the eighteen brachiopod taxa comprising the Treiorwerth assemblage, the generic identification of six is uncertain and they are excluded from consideration here; six belong to endemic genera, i.e. genera known only from the Ffynnon-y-mab locality and from the Tagoat Beds in south-east Ireland (Brenchley *et al.* 1967, p. 388). Of the remaining six genera, four (*Orthambonites*, *Productorthis*, *Tritoechia*, and *Rugostrophia*) are elsewhere associated only in the Summerford Group and related formations, one (*Hesperonomiella*) was previously reported from the Whiterock Stage in North America (Cooper 1956, pp. 337–338), and one (*Skenidioides*) is the oldest occurrence of a genus of widespread distribution in younger Ordovician and Silurian rocks.

The seven taxa of the Bod Deiniol assemblage also occur in the Summerford Group. Although five of these (*Ahtiella*, *Productorthis*, *Orthambonites*, *Platystrophia*, *Antigonambonites*) also occur in rocks of late Arenig and Llanvirn age in Estonia, two (*Atelelasma* and *Taffia*?) are North American genera that are associated with the Baltic genera only in the Summerford Group and related formations.

Other penecontemporaneous British and Irish brachiopod assemblages are significantly different from those of the Treiorwerth and Bod Deiniol formations—differences that have led to the identification of discrete palaeogeographic provinces and inferences concerning their relative positions in the light of plate tectonics. The

closest similarity of the Anglesey assemblages is with the Ogof Hên Formation (lower Arenig) of Ramsey Island, Pembrokeshire (Bates 1969), whose two brachiopod genera (*Monorthis* and *Orthambonites* [= *Lenorthis*]) are represented by different species in the Treiorwerth Formation.

A greater contrast is exhibited by the brachiopods of west-central Ireland that are more readily equated with the North American Whiterock Stage than with a precise level in the British upper Arenig–lower Llandeilo succession. Of the seven genera in the Mweelrea Grits at Uggool (Williams 1972), only one (*Hesperonomiella*) occurs in the Treiorwerth or Bod Deiniol assemblages. A similar brachiopod assemblage from the Tourmakeady Limestone from near-by County Mayo, though unreported, was included in the Scoto-Appalachian biogeographic province by Williams (1973, pp. 248–249).

The brachiopods of the Shelve District (Williams 1974), 80 miles (128 km) to the south-east of Anglesey, show as much contrast but of a different kind. Of the eleven genera of articulate brachiopods in the late Arenig Mytton Flags, only the cosmopolitan *Orthambonites* (= *Lenorthis*) was seen also in the Treiorwerth Formation. It may also be noteworthy that both formations contain an early skenidioid species, the one in the Mytton Flags placed in the monotypic *Protoskenidioides* (Williams 1974, p. 83) while the Treiorwerth species is here treated as an unnamed species of the long-ranging genus *Skenidioides*. There are two few articulate brachiopods in the beds of Llanvirn age at Shelve for meaningful comparison, but it may be significant that the upper Llanvirn Weston Beds yielded the oldest species yet recorded of the Mediterranean heterorthid genus, *Tissintia* Havlicek. The Mytton Flags brachiopod assemblage was included in the Anglo-French brachiopod biogeographic province by Williams (1973, pp. 248–249).

Explanations for the present-day geographic proximity of such distinctive biogeographic provinces have been made by postulating ancient palaeogeographies permitted by plate tectonics (e.g. Whittington and Hughes 1972; Smith *et al.* 1973; Ross 1975; Hughes *et al.* 1975). The special position of the Celtic Province as a group of islands in the middle of the Proto-Atlantic (or Iapetus) Ocean has been shown on palaeogeographic maps (Dean 1976; Neuman 1976). So placed, the Irish Sea horst in late Arenig time was separated from the Welsh Borderland by a wide expanse of ocean.

Present understanding of the geology between Anglesey and the Welsh Borderland (Williams 1976, p. 34) does not support the former existence of an ocean in this area. Throughout Wales Lower Palaeozoic rocks are underlain by continental crust of near normal thickness (Blundell and Parks 1969) rather than by oceanic crust. If there was Ordovician and older oceanic crust here, it has been destroyed and is now represented by one or more sutures that have not yet been identified as such.

Some aspects of the Ordovician rocks themselves suggest continuity across this region. The basal Arenig sandstones of Anglesey (Carmel Formation) are lithologically like those of Shelve (Stiperstones Quartzite), and faunally like those of Pembrokeshire (Ogof Hên Formation) and the Arenig region (Henllan Ashes) in their low-diversity *Orthambonites-Megalaspidella* faunas. Further, the northwestward overstepping by Arenig sandstone from the Upper Cambrian on to the Precambrian Gwna Group (equated with part of the Mona Complex: Smith and

George 1961, p. 27) suggests that little horizontal displacement occurred after that transgression apart from that due to folding of the Ordovician rocks.

Thus, re-examination of the brachiopods from the Treiorwerth and Bod Deiniol formations demonstrates the distinctness of the association of brachiopod genera constituting the Celtic biogeographic province, and the similarity of this association in Anglesey and south-eastern Ireland with those in peri-insular volcaniclastic rocks in Maine, New Brunswick, and Newfoundland. The differences between this province and the penecontemporaneous Scoto-Appalachian province to the north-west, and the Anglo-French province to the south-east, are thereby heightened. Although evidence of many kinds indicates that the original distance between the Celtic province of Anglesey and the Scoto-Appalachian province of western Ireland and southern Scotland was greatly reduced by the closing of the Iapetus Ocean, similar evidence is not available to explain the contrasts between Anglesey and the Anglo-French province of the Welsh Borderland. It is possible, therefore, that these contrasts are due as much to local environmental factors as they are to geographic isolation.

SYSTEMATIC PALAEONTOLOGY

All but two of the eighteen brachiopod taxa of the Treiorwerth Formation are described or discussed and illustrated in the following section, as are five of the seven taxa from the Bod Deiniol Formation. No significant new information beyond that given by Bates (1968) was obtained for the four taxa from these formations not discussed here. Virtually all the specimens studied were obtained from the samples collected by both authors and shipped to the U.S. National Museum of Natural History, Washington, D.C., where they were accessioned (USNM no. 296269). Type, illustrated and the individual specimens whose measurements are given in this paper have been deposited in the Department of Palaeontology, British Museum (Natural History) and assigned register numbers BB73422–73531 and BB74070–74077. Representative specimens of those species available in reasonable quantities have been retained in the brachiopod collection of the U.S. National Museum. The remainder of the collection is housed at the British Museum.

Preservation imposes constraints on the taxonomic treatment of these brachiopods. In the absence of conjoined shells, counterpart dorsal and ventral valves have been identified by combinations of consistent attributes seen as internal and external moulds. Such preservation precludes confirmation of shell structure inferred by the suprageneric assignments because most specimens are not identifiable prior to removal of the shell.

Although this kind of preservation permits observation of the presence or absence of those features that form the basis for generic identification, details of proportion and ornament are generally not well enough preserved for specific discrimination. Most taxa identified to species, therefore, are those belonging to monotypic genera not yet known outside this area; and the others are identified as unnamed species of established genera or higher categories with varying degrees of confidence.

Details of the number of specimens studied, and their stratigraphic occurrence are given in Tables 1 and 2.

Class INARTICULATA Huxley, 1869
Order ACROTRETIDA Kuhn, 1949
Suborder CRANIDINA Waagen, 1885
Superfamily CRANIACEA Menke, 1828
Family CRANIIDAE Menke, 1828
Genus PETROCRANIA Raymond, 1911

Petrocrania? sp.

Plate 63, figs. 1, 2

Description (one dorsal valve only). Large, subelliptical, length (20 mm) about one-tenth greater than width (18 mm); posterior margin vague, apparently bluntly tapered; sides and front broadly rounded.

Asymmetrically conical in lateral profile, beak at apex near centre (thickness 3 mm); posterior slope slightly concave behind beak, becoming nearly planar to posterior margin; anterior slope gently convex to anterior margin. Anterior profile with slight median carination, sides broadly arched. Surface ornament of closely spaced, fine growth lines.

Interior with two pairs of small, elliptical adductor scars; long axes of ellipses of both pairs converging anteromedially at about 60°; anterior scars at midlength, flanking apex, more widely spaced and slightly larger than posterior pair at one-third shell length.

Discussion. The external ornament of closely spaced growth lines only suggests assignment of this specimen to *Petrocrania*, but the specimen is larger and more elongate than is common for the genus. The generic identification thus remains questionable in the absence of additional specimens.

The Treiorwerth samples yielded four additional craniid dorsal valves, all poorly or incompletely preserved. Two of these, represented by internal moulds only, are transversely quadrate in outline, with impressions of a shallow anterior sulcus, and very large anterior muscle scars; they are thus not conspecific with the specimen described here, but similarly shaped shells from the Middle Ordovician Effna Limestone of B. N. Cooper (1944) in Virginia were named *Petrocrania? magna* by G. A. Cooper (1956, p. 289).

Order KUTORGINIDA Kuhn, 1949

Superfamily, family, genus, and species unknown

Plate 63, figs. 3, 4; text-fig. 2

Description. Large, elongate, elliptical, ventribiconvex, rectimarginate shells. Ventral valve extended posteriorly, about one-fifth longer than wide; single available dorsal valve incomplete, presumably shorter, without posterior extension. Outline with broadly rounded sides and front; ventral valve extended to narrowly rounded apex. Anterior profile domed in median sector, with gently sloping sides. Thickness of ventral valve about one-fifth its length, about twice that of dorsal valve. Ventral interarea long, about one-quarter shell length, apsacline, about 30° from commissural plane, with large apical foramen; surface marked by strong, straight, closely spaced growth lines parallel to anterior edge. Shell material bluish-grey opaline silica. External surface with fine growth lines throughout, and low concentric wrinkles around anterior margins.

EXPLANATION OF PLATE 63

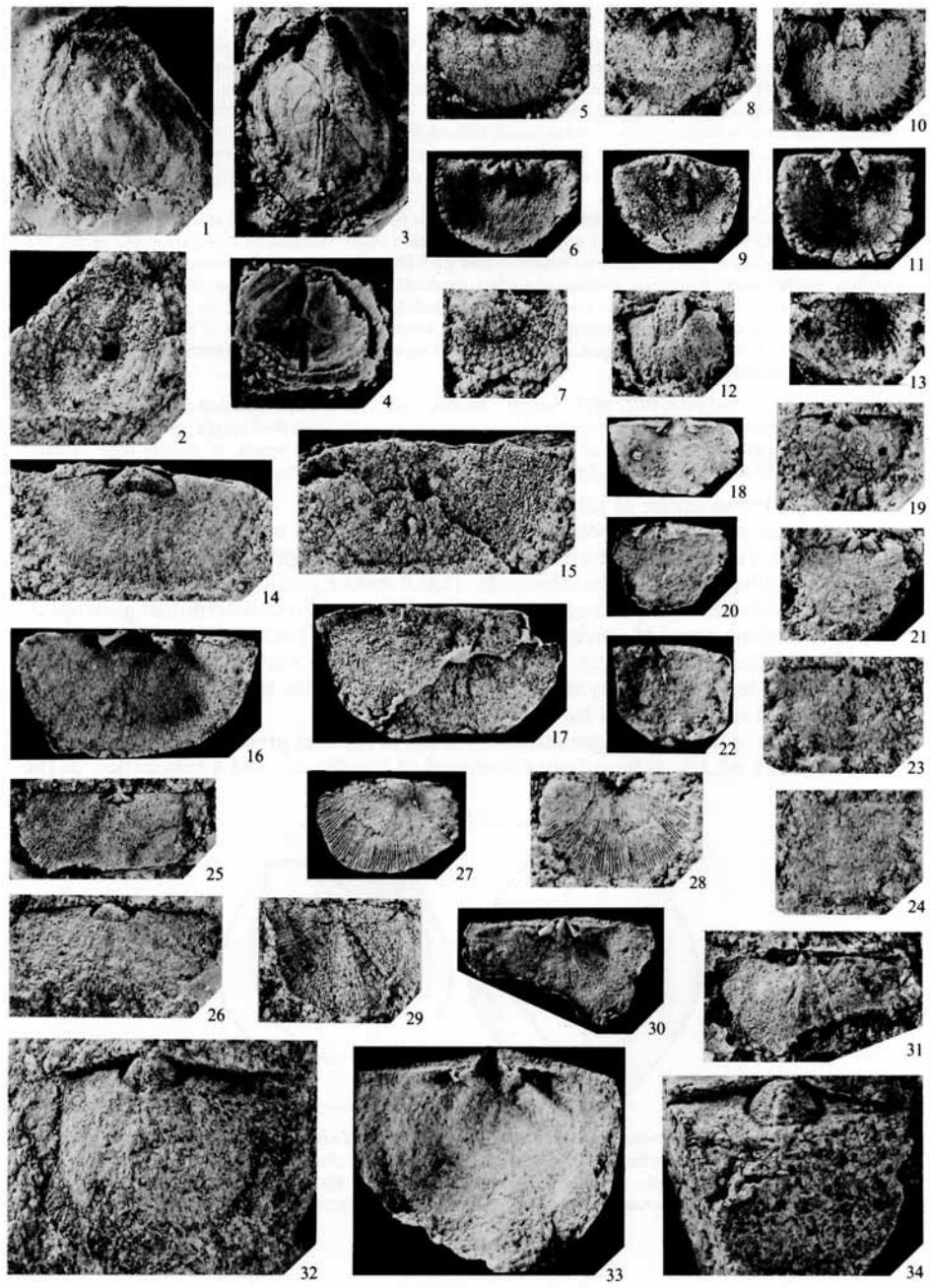
Figs. 1, 2. *Petrocrania*? sp., ×1·5; dorsal valve, BB73422, internal and external mould.

Figs. 3, 4. Kutorginidaid, superfamily, family, genus, and species unknown, ×1·5; 3, ventral valve, BB73423, internal mould; opaline mineralized shell was removed in preparation of the specimen; 4, dorsal valve, BB74070, interior of silicified shell.

Figs. 5–13. *Productorthis* sp., ×3; 5–7, dorsal valve, BB73447, internal mould, internal replica, partial external mould; 8, 9, dorsal valve, BB73448, internal mould, internal replica; 10, 11, ventral valve, BB73449, internal mould, internal replica; 12, 13, ventral valve, BB73450, internal mould, external mould.

Figs. 14–28. *Treioria chaulioda* sp. nov., ×2; 14–17, holotype, ventral valve, BB73432, internal mould, external mould, internal replica, external replica; 18, 19, paratype, dorsal valve, BB73430, internal replica, internal mould; 20, 21, paratype, dorsal valve, BB73429, internal replica, internal mould; 22–24, paratype, dorsal valve, BB73428, internal replica, internal mould, external mould; 25, paratype, ventral valve, BB73433, internal mould; 26, paratype, ventral valve, BB73435, internal mould; 27, 28, paratype, ventral valve, BB73498, external replica, external mould.

Figs. 29–34. *Hesperonomiella* sp., ×1·5; 29, dorsal valve, BB73425, external mould; 30, 31, dorsal valve, BB73424, internal replica, internal mould; 32, 33, ventral valve, BB73427, internal mould, internal replica; 34, ventral valve, BB73426, internal mould.



NEUMAN and BATES, early Ordovician brachiopods

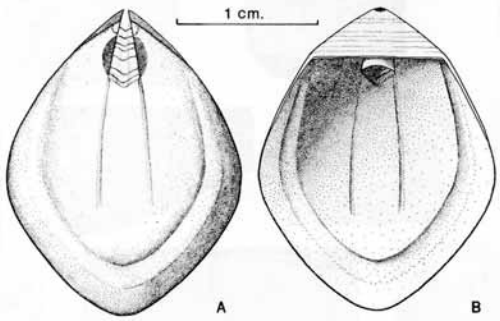
Preserved part of dorsal interior with pattern of shallow concavities and low ridges interpreted as two pairs of adductor muscle scars. Each of posterior pair (one preserved) elliptical in outline, about three times longer than wide, parallel to posterolateral margin to about one-third shell length. Anterior scars occupy middle half of shell floor, separated from posterior scars by low, widely divergent ridges, and from each other by low median ridge; each scar triangular in outline, with posterior apex near midline of shell, expanding anterolaterally to widely spaced anterolateral termination somewhat beyond shell midlength; middle of shell beyond midlength with narrow groove that extends to near anterior margin. Anterior margin of thickened shell.

Ventral interior with long, anteriorly expanding pedicle tube enclosed in cone ankylosed to shell floor. Sides and dorsal surface of cone free except near apex where short, laterally directed strut-like plates link its sides to junction of inner surface of interarea and shell floor. Pedicle tube somewhat elliptical in cross-section, slightly wider than high, its internal surface marked by strong annular scars and weak longitudinal ridges and furrows. Inner surface of interarea free-standing, supported only at its posterolateral sides. Mantle canals (probably *vascula lateralia*) subparallel, extending from junctions of sides of pedicle tube with shell floor nearly to shell margin. Muscle scars not seen on shell floor. Shell thickened and furrowed around anterolateral margin.

Measurements. Dorsal valve (BB74070): length—10 mm preserved, 16 mm estimated complete; maximum width—15 mm preserved, 16 mm estimated complete, at 8 mm (estimated) shell length; thickness—1·5 mm. Ventral valve (BB73423): length—22 mm; length of interarea—5 mm; length of pedicle tube—4 mm; hinge width—10 mm; maximum width—17 mm at 12 mm shell length; thickness—4 mm.

Discussion. Preservation of all specimens as opaline silica, unlike that of any of the thousands of brachiopod specimens of other species seen in the preparation of the Treiorwerth Formation material, indicates that their original mineral composition was different from the other brachiopods. That it was originally aragonite is suggested by the one other similarly preserved fossil, a specimen of an undetermined gastropod, the only mollusc seen (*Matherella* (?) *acuticostata* Bates (1963, p. 258) was, however, completely decalcified). Thus, during diagenesis silica may have substituted for aragonite, filling cavities or by replacement, similar to calcite substitution of aragonite of trimerellid shells reported by Jaanusson (1966).

The effects of tectonic deformation, apparent in the best preserved specimen in the collection (Pl. 63, fig. 3) have been eliminated in text-fig. 2*a*, and a restoration of the



TEXT-FIG. 2. Restorations of ventral valve of kutorginidaid, superfamily, family, genus, and species unknown, based mainly on BB73423; A, internal mould with effects of deformation removed; B, interior of valve; drawings by Janine Higgins.

ventral valve based on this and other specimens has been constructed (text-fig. 2*b*). Thus visualized, the species appears to be new to the fossil record, especially in its long, unsupported, planar interarea with an apical foramen, together with its pedicle tube. These features may have developed from the early Cambrian Kutorginida, with which they are here classified, whose shells are of unspecified calcareous composition. In over-all proportions and size, and by inference, its aragonite shell, this species seems also to be related to the Trimerellidae whose earliest genus, *Eodinobolus*, has significantly different architecture, and appears somewhat later, in the Middle Ordovician.

Class ARTICULATA Huxley, 1869
Order ORTHIDA Schuchert and Cooper, 1932
Suborder ORTHIDINA Schuchert and Cooper, 1932
Superfamily ORTHACEA Woodward, 1852
Family HESPERONOMIIDAE Ulrich and Cooper, 1936
Genus HESPERONOMIELLA Ulrich and Cooper, 1936

Hesperonomiella sp.

Plate 63, figs. 29–34

Description. Moderate to large, ventribiconvex, subquadrate, maximum width at hinge greater than length, cardinal extremities somewhat extended, acute. Sides nearly straight through middle third, anteriorly convergent, front broadly rounded. Dorsal interarea anacline, short; notothyrium bordered by narrow chilidial plates; ventral interarea apsacline, about twice as long as dorsal interarea; delthyrium open, unmodified. Dorsal sulcus moderately deep, wide, originating at beak; maximum thickness near mid-length. Ventral valve about twice depth of dorsal valve; fold less conspicuous than dorsal sulcus. Ornament multicostellate, eighteen to twenty costellae per 5 mm at front of large- and medium-size shells; branching pattern not known. Concentric ornament of weak growth lines, widely and variably spaced.

Dorsal interior with low, short notothyrial platform of thickened shell bearing simple, posteriorly expanded cardinal process not extending to front of platform. Brachiophores short, rod-like extensions of sides of notothyrial platform. Socket floors shallow excavations in thickened shell tissue of posterior shell wall. Adductor muscle scars quadripartite with low, broad myophragm; posterior pair small, oval; anterior pair about three times larger than posterior pair, subtriangular, anteriorly expanded. Mantle canal system not seen.

Ventral interior with stout teeth having broad bases, ventrally divergent dental plates with receding anterior margins whose bases form posterior half of lateral margins of muscle field. Muscle field triangular; anterior margin broad arc of thickened shell. Adductor track about equal in width to diductor scars, set slightly below them. Mantle canal system not seen. Shell thickened around anterolateral margins of some specimens.

Discussion. The three dorsal valves assigned to this unnamed species are all somewhat smaller than the ventral valves assigned to it. The ornament of both valves, though indifferently preserved, is the same; thus linked, the interiors are those diagnostic of the genus.

H. carmelensis Bates 1968 (pp. 142–143) from the Carmel Formation, Anglesey, differs from the Treiorwerth Formation species in having a more rounded outline, with a hinge-width less than maximum width and cardinal extremities that are rounded compared to the extended cardinal extremities of the Treiorwerth Formation species. *Hesperonomiella* species in North America, with the exception of *H. quebecensis* Cooper, 1956 (p. 337) from boulders in the Mystic Conglomerate in Quebec,

are known from specimens that are much smaller than those from the Treiorwerth Formation. The Quebec species too is widest at the hinge, but internally its dorsal valve has a median ridge, and its delthyrial cavity is narrower than that of the Treiorwerth species.

TABLE 3. Measurements of *Hesperonomiella* sp.

BB no.	Length					Width				Thickness
Dorsal valves	total	notothyrial platform	posterior adductor scar	anterior adductor scar	inter-area	hinge	notothyrial platform	posterior adductor scar	anterior adductor scar	
					(mm)					
73424	11(13)	2	3	7	.75	20	3	4	6	2
73425	12	–	–	–	–	16	–	–	–	–
Ventral valves			muscle field				diductor scar(ea.)		adductor scar	
73426	20		5		2	25	2.5		2	4
73427	24		5		2	29	2		2.5	3

( )Estimated measurement

Genus TREIORIA gen. nov.

Diagnosis. Hesperonomiid with strong teeth and posteriorly confined musculature, both notothyrial platform and ventral muscle scars significantly wider than long.

Type species. Treioria chaulioda sp. nov.; no other species assigned.

Description. Transverse, semi-elliptical, thin-bodied planoconvex to resupinate shells; interareas short, ridge-like chilidial plates; delthyrium open, unmodified; multicostellate. Cardinalia orthoid, with thin, simple cardinal process, notothyrial platform twice as wide as long, brachiophores short, with bases on shell floor; sockets without fulcral plates or thickened floors. Ventral valve with large teeth, dental plates strongly divergent, muscle field width generally twice or more its length, with wide adductor track about equal to adductor scars in length. Shell structure and mantle canal systems unknown.

Discussion. This monotypic genus resembles *Hesperonomia*, but differs from that genus in the reduced length of its notothyrial platform and ventral muscle scars, and in the large size of its teeth.

Treioria chaulioda sp. nov.

Plate 63, figs. 14–28

Holotype. Ventral valve, BB73432 (Pl. 63, figs. 14–17).

Derivation of name. Greek *chaulios* (prominent) and *odous* (tooth).

Description. Shells wider than long, widest at hinge, one-third to one-half greater than length, cardinal extremities acute, outline broadly curved. Dorsal interarea very short, anacline, about two-thirds length of steeply apsacline ventral interarea. Lateral profile wedge-like, maximum thickness immediately in front of hinge, tapering forward with little or no curvature; dorsal valve nearly flat, ventral valve sharply concave immediately in front of beak, becoming broadly convex, flat or slightly concave at midlength. In anterior profile dorsal sulcus shallow, broad, bordered by flanks of low convexity; posterolateral extremities slightly deflexed ventrally; ventral fold correspondingly low, lateral slopes slightly concave. Lateral commissure straight, anterior commissure broadly sulcate. Multicostellate ornament of rounded costellae, five to six per mm through shell length, increasing in number by intercalation. Concentric ornament lacking or obscure. Impunctate shell structure inferred from absence of papillae on internal moulds.

Dorsal interior with short, low notothyrial platform, gently inclined posteriorly, sides steeply sloping, anterior margin thickened forming low transverse ridge; cardinal process low, thin, traversing full length of platform. Brachiophores short extensions of sides of notothyrial platform, with bases extending to shell floor. Shell floor smooth except for median undulation corresponding with sulcus; diductor muscle scars and mantle canal system not preserved; radial ornament weakly impressed well into midpart of shell.

Ventral interior with prominent teeth (anomalously preserved by appression of internal and external surfaces of palintrope beyond teeth and supporting structures); dental plates widely flared, erect, receding. Delthyrial cavity shallow; muscle field very short, less than one-fifth of total shell length, confined to cavity, one and a half to three times wider than long, posteriorly sloping; anterior margin slightly thickened. Adductor tracks set somewhat above diductor scars, relative lengths variable, some slightly shorter, some longer. Shell floor featureless except for impression of radial ornament from shell margin into midpart of shell as in dorsal valve.

TABLE 4. Measurements of *Treioria chaulioda* gen. et sp. nov.

BB no.	Length			Width		Costellae
Dorsal valves	total	notothyrial platform	interarea	hinge	notothyrial platform	
			(mm)			(per mm)
73428 (p)*	8	1	1	8(13)	2.5	–
73429 (p)*	7.5	1.5	1	9(12)	3	–
73430 (p)*	6.5	1.5	.5	11	3	6
73431 (p)	10(11)	1	.5	10	2.5	–
Ventral valves		muscle field			muscle field	
73432(h)*	11	2	1.5	19	5.5	5
73433(p)*	6(8)	1	1	13(15)	3	6
73434(p)	8	1.5	1	11(13)	2.5	5
73435(p)*	9	1.5	1.5	17	3	–
73498(p)*	8	–	–	11(13)	–	5

(h)Holotype, (p)Paratype, *Figured specimens, ( )Estimated measurements

Discussion. The distinctive features of this species are as those described above for the genus. Although preservation of the specimens upon which it is based prevents direct observation of shell structure, and gives a false impression of the hinge areas of the ventral valve, most major elements of the morphology of both valves are sufficiently well preserved to indicate that no species having these characteristics has been described before.

Family ORTHIDAE Woodward, 1852
Subfamily ORTHINAE Woodward, 1852
Genus ORTHAMBONITES Pander, 1830

Orthambonites sp.

Plate 64, figs. 1–11

1968 *Lenorthis* sp. Bates, p. 148, pl. 2, figs. 11, 12.

Description. Small to medium, semicircular to semi-elliptical, ventribiconvex shells, with shallow dorsal sulcus and low ventral fold. Maximum width at hinge, equal to or as much as one-third greater than length. Lateral profile broadly rounded, maximum thickness at about one-third shell length, dorsal valve half as deep as ventral valve. Costae and interspaces V-shaped in profile, about five per 5 mm in midsector at 8 mm shell-length. Ventral valve bears median costa, dorsal valve a corresponding interspace.

Dorsal interior with low, short notothyrial platform; cardinal process thin, blade-like; brachiophores short, with stout, divergent bases and sharply pointed terminations. Median ridge variable; low, short, extending to midlength in some specimens, absent in others. Adductor muscle scars and mantle canals not seen. Ornament imprinted on interior through most of shell length, impressions of interspaces wider than those of costae.

Ventral interior with stout, wide teeth; dental plates short, erect, receding, joined to shell floor at mid-length of sides of muscle field. Muscle field slightly thickened at front, adductor scar about one-third width of field, about equal in length to diductor scars. Mantle canal system not impressed, internal imprint of ornament as on dorsal valves.

TABLE 5. Measurements of *Orthambonites* sp.

BB no.	Length		Width		Thickness	Costae
Dorsal Valves	total	notothyrial platform	total	notothyrial platform		
			(mm)			
73436*	9.5	1	14	2	1.5	18
73437	6	1	9	1	1	14
73438*	6	1	10	1.5	1	16
73439	5	.75	8	1.5	.75	18
73440	7.5	.75	10	1	1	16
Ventral valves		muscle field		muscle field		
73441	8	2	9	1.5	2	15
73442*	8	3.5	7(10)	1.5	2	17
73443	9	3	11	2	2.5	19
73444	9	3	6(9)	2	2.5	11(17)
73445	8	2	6(9)	1.5	1.75	15
73446*	8	2	9	2	1.75	19

*Figured specimens, ( )Estimated measurements

EXPLANATION OF PLATE 64

Figs. 1–11. *Orthambonites* sp., ×2; 1, 2, dorsal valve, BB73436, internal mould, internal replica; 3–5, dorsal valve, BB73438, internal mould, internal replica, partial external mould; 6–9, ventral valve, BB73442, internal mould, internal replica, partial external mould, partial external replica; 10, 11, ventral valve, BB73446, internal mould, internal replica.

Figs. 12–23. *Skenidioides* sp. (1) Bates, ×5; 12–15, dorsal valve, BB74071, internal mould, external mould, internal replica, external replica; 16, 17, dorsal valve, BB74073, internal mould, internal replica; 18, 19, ventral valve, BB74077, internal mould, internal replica; 20–23, ventral valve, BB74074, internal mould, internal replica, external mould, external replica.

Figs. 24–38. *Paurorthis*? sp., ×3; 24–26, dorsal valve, BB73483, internal mould, external mould, external replica; 27, 28, dorsal valve, BB73484, internal mould, internal replica; 29, 30, dorsal valve, BB73488, internal mould, internal replica; 31, dorsal valve, BB73486, internal mould; 32, dorsal valve, BB73485, internal mould; 33, ventral valve, BB73492, internal mould; 34, ventral valve, BB73491, internal mould; 35–38, ventral valve, BB73490, internal mould, internal replica, external mould, external replica.

Figs. 39–49. *Tritoechia pyramidalis* (Bates), ×2; 39, 40, dorsal valve, BB73495, internal mould, internal replica; 41–44, dorsal valve, BB73493, internal mould, external mould, external replica, internal replica; 45, ventral valve, BB73498, external mould, posterior view, showing radial striations (Bates photo.); 46, ventral valve, BB73497, internal mould; 47–49, ventral valve, BB73496, external mould, internal mould, external replica.

NEUMAN and BATES, early Ordovician brachiopods

Discussion. Coarse-ribbed orthids of this kind are common components of early Ordovician brachiopod assemblages. Similar shells have been placed in several genera, including *Orthis*, *Orthambonites*, *Hesperorthis*, *Plectorthis*, and *Lenorthis*, distinctions among them generally being the characteristics of the cardinalia and musculature. An exception to such criteria as the basis of generic discrimination is *Lenorthis* Andreeva, 1955, in which a distinguishing characteristic is given (Andreeva 1955, p. 69, translated by J. W. Cooper) as the divergent pallial sinuses in the ventral valve. Andreeva (*in* Nikiforova and Andreeva 1961, p. 73, translated by V. Jaanusson) later found that specimens included in *L. girardi*, the type species of the genus, belonged to two other genera, *Hesperorthis* and *Mimella*, and she recommended that the genus be abandoned. Accordingly, *Lenorthis* is a subjective junior synonym of either *Hesperorthis* or *Mimella*, depending on the designation and identification of the holotype of the species *girardi*, information not evident from the original description or the accompanying illustrations and their captions. Williams, however, included *Lenorthis* in the *Treatise on invertebrate paleontology* (Williams *et al.* 1965, pp. 311–313), distinguishing it from *Orthis* by its biconvexity and the divergence of the proximal parts of its *vascula media*, and assigned to it the species originally described as *Orthambonites mostellerensis* Cooper. Such an assignment is invalid, as is the assignment to it of '*Orthis*' *proava* Salter (Bates 1968, p. 146) and all subsequent usages of the name *Lenorthis*.

'*Lenorthis proava* (Salter)' was listed as occurring in the Treiorwerth Formation at Ffynnon-y-mab (Bates 1968, p. 134), but the occurrence of the species in this formation at this or any other locality was not mentioned in the redescription of the species (Bates 1968, p. 147), the specimens described having come from the Carmel Formation.

The most apparent difference between the *Orthambonites* sp. in the Treiorwerth Formation and the Carmel species is the relative prominence of the median ridge in the dorsal valve of the latter, whereas this ridge is either poorly developed or absent in the Treiorwerth species. Ventral valves of the Carmel species also have somewhat longer dental plates than those of the Treiorwerth species. The *vascula media* of the two species cannot be compared as they are not preserved in the Treiorwerth specimens.

The proportions and ornament of *Orthambonites* sp. from the Bod Deiniol Formation are the same as those from the Treiorwerth Formation, and specimens of the same size from both formations are identical internally; they are therefore considered to be conspecific. Some Bod Deiniol specimens, 15–19 mm wide, are larger than any from the Treiorwerth Formation; these large ventral valves have wide, parallel to narrowly divergent *vascula media*, and dorsal valves of similar sizes have quadripartite adductor muscle scars.

Subfamily PRODUCTORTHINAE Schuchert and Cooper, 1931

Genus PRODUCTORTHIS Kozlowski, 1927

Productorthis sp.

Plate 63, figs. 5–13; Plate 68, figs. 1–11

1968 *Panderina lamellosa* Bates, p. 151, pl. 3, figs. 10–18.

Discussion. Specimens from the Treiorwerth and Bod Deiniol formations identified as *Panderina lamellosa* by Bates (1968) are here assigned to the genus *Productorthis*.

The specimens from both formations have the biconvexity, lamellose exterior, and internal features of this genus, and lack interareas. The species *lamellosa*, erected by Bates for specimens from the Treiorwerth Formation, is therefore redundant because imbricate growth lamellae which were held to distinguish it from other species of *Panderina* are characteristic of all species of *Productorthis*. Assignment of these shells to any species of *Productorthis*, is, however, prohibited by their poor preservation.

In the few dorsal valves of large specimens from the Bod Deiniol Formation the adductor muscle scars are more deeply impressed and the median ridge between them is more pronounced than in the smaller specimens from the Treiorwerth Formation. In other respects the specimens from the two formations are similar except for size, those from the Treiorwerth Formation having the same dimensions as those treated by Bates as indicated by the following measurements.

	Length (mm)	Width (mm)		Length (mm)	Width (mm)
TREIORWERTH FORMATION SPECIMENS			BOD DEINIOL FORMATION SPECIMENS		
Dorsal valves			Dorsal valve		
BB73447	5	8	BB73451	8	12
BB73448	5	7	Ventral valves		
Ventral valves			BB73452	9	10
BB73449	6	7	BB73453	8	8
BB73450	5	6	BB73454	8	9

Family PLECTORTHIDAE Schuchert, 1929
Subfamily PLATYSTROPHINAE Schuchert, 1929
Genus PLATYSTROPHIA King, 1850

Platystrophia? sp.

Plate 68, figs. 17–24

Description. Dorsibiconvex, narrow-hinged, coarsely costate, of medium size for genus. Maximum width at midlength or beyond, about twice hinge width, cardinal extremities obtuse. Interareas planar, nearly equal in length, both apsacline; notothyrium and delthyrium open, unmodified. Dorsal beak higher, more incurved than that of ventral valve; dorsal fold prominent through entire shell length, steep-sided in anterior half, includes angle of about 25°. Flanks swollen, convex. Anterior commissure strongly plicate. Costellae angular, four on fold, three in sulcus, five or six on each side; growth lamellae and pustules, if present, not preserved.

Dorsal interior with deeply set, triangular notothyrial platform of thickened shell; cardinal process thin, blade-like, extending full length of platform. Brachiophores lath-like, with stout bases, joined to posterior shell wall by fulcral plates. Adductor muscle scars quadripartite; posterior pair short, oval; anterior pair elongate, about three times longer than posterior pair. Myophragm low, rounded posteriorly; thin, sharp-crested between anterior adductor scars. Mantle canal system not seen. External ornament impressed as shallow undulations of shell margin.

Ventral interior with stout teeth; dental plates thick, divergent, advancing, merged at their bases with sides of posterior half of muscle field. Muscle field medially elongate, pseudospondylium with thickened anterolateral margins beyond bases of dental plates. Adductor track about three times width of each diductor scar at midlength of field, slightly elevated above them. Thickening of anterior margin of pseudospondylium most pronounced in middle, with bluntly pointed median extension. Mantle canal system not seen; internal impression of ornament as in dorsal valve.

Discussion. This species is assigned to *Platystrophia* questionably because no specimen of it preserves ornament in sufficient detail to permit determination of the presence

TABLE 6. Measurements of *Platystrophia*? sp.

BB no.	Length					Width		Costae	
Dorsal valves	total		notothyrial cavity	adductor muscle scar	inter-area	hinge	maximum at specified length		
	projected	circumference							
	(mm)								
73455*	13	15	2.5	–	1.5	8(11)	12(18)/10	–	
73456*	14	18	2.5	9	2	10(12)	13(22)/10	–	
Ventral valves			muscle field					sulcus	flanks
73457*	10	11	4.5		1.5	8	15/7	3	10
73458	13	16	4		1.5	10(12)	13(17)/8	3	10

*Figured specimens, ( )Estimated measurements

or absence of the pustulose shell surface characteristic of the genus. The costation of its fold and sulcus is like that of the tricostate group of *Platystrophia* (Schuchert and Cooper 1932, p. 67), whereas similar shells in earlier Ordovician assemblages in the Baltic region and in the northern Appalachians have costation like that of the bicostate species group (Rubel 1961, pp. 154–156, pls. 1, 2; Neuman 1964, p. E17, pl. 2, figs. 12–18; Neuman 1976, p. 21, pl. 2, figs. 9–12).

Genus RHYNCHORTHIS Bates, 1968

1968 *Rhynchorthis* Bates, p. 160.

Revised diagnosis. Rostrate dorsibiconvex shells with short, narrow interareas, delthyrium and notothyrium open, ornament of angular, V-shaped costae and subdued growth lamellae; anterior commissure plicate. Dorsal interior orthoid, with long curved brachiophores projecting into ventral valve; fulcral plates present, median septum absent, myophragm narrow, short, between anterior diductor muscle scars. Ventral interior with short teeth, short, thick, receding dental plates; ventral muscle field medially elongate with thickened anterolateral margins. Shell structure unknown.

Discussion. Additional information on the type species, *R. rotundus*, obtained from a suite of topotype specimens better preserved than those available at the time the genus was erected provide the basis for this revised diagnosis. These specimens leave no doubt as to the rhynchonelliform characteristics, both externally and internally.

Emendations of the concept of the genus indicated by the new material are: 1, the ornament consists of angular, V-shaped costae rather than rounded ones, and growth lamellae are present; 2, a dorsal fold and ventral sulcus are present but variable in their amplitude; 3, the brachiophores are elongate, curved blades set vertically at the sides of the narrow notothyrial platform, their concave edges posterior and their distal tips extending above the commissure into space contained within the ventral valve; 4, sockets are elevated above the shell floor on thickened shell, their anterior margins formed by fulcral plates; 5, dental plates, although receding, and of reduced length at midheight, are thick throughout, and do not suggest obsolescence; 6, the medially elongate ventral muscle field contains a wide adductor track set slightly

above the diductors, and its anterolateral margin is thickened to form a pseudospondylium.

We now consider it likely that *Rhynchorthis* is a plectorthid most closely allied to *Platystrophia*, differing from that genus primarily in hinge-width and in modifications of the cardinalia that seem appropriate to a narrow-hinged form of this derivation. The Angusticardiniidae, to which *Rhynchorthis* was previously assigned, have cardinalia that are more rhynchonellid than orthid, their brachiophores converging on to a median septum (Williams *in* Williams *et al.* 1965, p. 344). The long, deep notothyrial platform of *Rhynchorthis*, and its long, thin brachiophores that approach the proportions of rhynchonellid crura suggest this or a similar genus as one possible rhynchonellid progenitor.

Shell structure of *Rhynchorthis* cannot be determined from presently available specimens of *R. rotundus*, the only species of the genus. By inference from its classification as a plectorthid, it may be impunctate and smooth or spinose, or exopunctate, all of which are found among the plectorthids.

Rhynchorthis rotundus Bates, 1968

Plate 66, figs. 1–26

1968 *Rhynchorthis rotundus* Bates, pp. 160–161, pl. 5, figs. 19–26.

Description. Rotund, tumid, subtriangular to pyriform, with weakly to moderately developed dorsal fold and corresponding ventral sulcus. Interareas short, narrow, at low angles to plane of commissure; length of dorsal interarea about half that of ventral valve. Maximum width at midlength, about twice hinge-width; length–width ratio variable, most commonly slightly longer than wide, more rarely equidimensional or slightly wider than long. Posterolateral sides diverge at 90–100°, broadly rounded at midlength and front. Fold of low to moderate height in anterior half of dorsal valve, sides subtending about 15°; sulcus defined at about midlength of ventral valves; flanks of both valves inflated. Dorsal valve thickness near middle about one-third its length; ventral valve slightly thinner. Lateral commissure straight, anterior commissure plicate, with subordinate zigzag pattern. Radial ornament of strong, angular, V-shaped costae, three on fold, two in sulcus, six to ten on each flank, diminishing in amplitude laterally. Concentric ornament of closely spaced, fine growth lamellae over entire shell surface, and one or more strong growth discontinuities near margins of some specimens.

Dorsal interior with long, narrow, deeply set notothyrial platform; cardinal process thin, blade-like, extending full length of platform, flanked in some specimens by pair of subsidiary ridges shorter and lower than cardinal process, and slightly concave inward. Sides of platform formed of thick brachiophore bases and shell tissue filling posterolateral extremities. Brachiophores erect, directed anteroventrally, tapering to curved blades that project beyond commissural plane. Fulcral plates well elevated above shell floor, forming margins of large sockets. Anterior margin of notothyrial platform merges with shell floor without marginal ridge. Adductor muscle scars quadripartite; posterior pair shallow, oval depressions close to brachiophore bases, one-third to one-half diameter of anterior pair; anterior adductor scars more deeply impressed, bilobed, separated from each other by short myophragm. Mantle canal system weakly impressed, probably lemniscate; *vascula media* narrow, subparallel, unbranched, extending forward from inner lobe of anterior adductor scar; *vascula myaria* unbranched, radiating from ridges dividing anterior adductor scars; *vascula genitalia* forming radial pattern of weakly impressed ridges and furrows for nearly full length of outer third of shell floor. Radial ornament variably impressed on shell interior, confined to margins in older, thick-shelled specimens, reflected by undulations into middle of younger, thin-shelled ones.

Ventral interior with thickened, medially elongate muscle field forming pseudospondylium about one-quarter shell length. Adductor track more than twice width of each diductor scar, elevated above them on thickened shell tissue. Median ridge variably developed; absent from some specimens, low and wide in others; maximum length about one-third length of pseudospondylium. Mantle canal system rarely impressed, where present saccate; *vascula media* wide, closely spaced, parallel from their origin at anterior

margin of adductor scars to about three-quarters shell length, then diverging to parallel shell margin, enclosing large area of shell floor occupied by radial pattern of weakly impressed ridges and furrows of *vascula genitalia*. Radial ornament impressed on shell interior as on dorsal valve.

TABLE 7. Measurements of *Rhynchorthis rotundus* Bates.

BB no.	Length				Width			Thickness	Costae
Dorsal valves	total	notothyrial platform	adductor muscle scars	inter-area	hinge	maximum at specified length	adductor muscle scars		
	(mm)								
73459	15	3.5	9	1	6	12/10	5	5	–
73460	12(16)	4	8	1.5	5	15/8	4	6	–
73461	13(15)	3	6	1	5	11/8	5	5	–
73462	13	–	–	–	–	14/7	–	4	17
73463	9	1.5	–	1.5	7	10/5	–	2	12
Ventral valves		muscle field					muscle field		
73465	16	6		2	8	15/8	4	3	16
73466	16	7		2	–	13/10	4	4	14
73467	14	5		–	–	14/6	4	3	14
73468	14	6		2	9	15/10	4	4	22

( ) Estimated measurements

Genus FFYNNONIA gen. nov.

Diagnosis. Biconvex, fascicostellate, with dorsal fold, ventral sulcus. Dorsal interior with short, wide notothyrial platform; cardinal process thin; brachiophore bases lateral extensions of notothyrial platform, free of shell floor but joined to posterior shell wall by fulcral plates. Ventral interior with short, wide teeth supported by short, receding dental plates; pseudospondylium present; adductor scars longer than diductor scars.

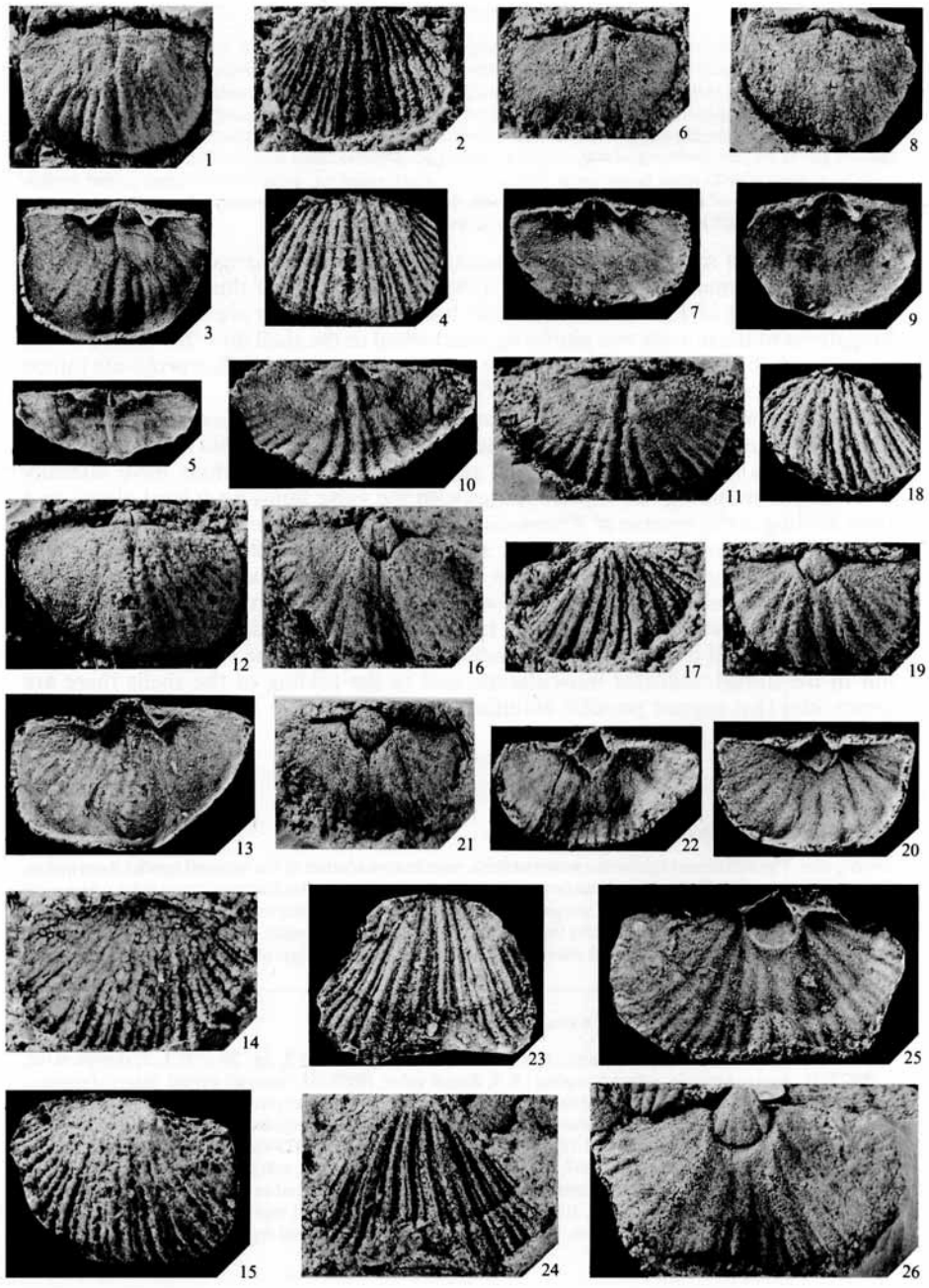
Type species. Pleurorthis costatus Bates, 1968; no other species assigned.

Derivation of name. From the Welsh word *Ffynnon* (English, well), as in Ffynnon-y-mab, well of the son.

Description. Dorsibiconvex, with contrast in convexity due to pronounced fold of dorsal valve in large shells. Interareas short, that of dorsal valve orthocline to gently anacline, about half length of concave, apsacline interarea of ventral valve. Notothyrium and delthyrium open, unmodified. Fascicostellate ornament of rounded, branching costellae.

EXPLANATION OF PLATE 65

Figs. 1–26. *Ffynnonia costata* (Bates), ×2; 1–5, dorsal valve, BB73469, internal mould, external mould, internal replica, external replica, internal replica tilted posteriorly to show absence of shell beneath brachiophores; 6, 7, dorsal valve, BB73474, internal mould, internal replica; 8, 9, dorsal valve, BB73473, internal mould, internal replica; 10, 11, dorsal valve, BB73471, internal replica, internal mould; 12–15, dorsal valve, BB73470, internal mould, internal replica, external mould, external replica; 16, ventral valve, BB73480, internal mould; 17–20, ventral valve, BB73477, partial external mould, partial external replica, internal mould, internal replica; 21, 22, ventral valve, BB73478, internal mould, internal replica; 23–26, ventral valve, BB73476, partial external replica, partial external mould, internal replica, internal mould.



NEUMAN and BATES, early Ordovician brachiopods

Dorsal interior with short, wide, notothyrial platform, thickened at anterior margin. Cardinal process low, thin. Brachiophore bases elevated lateral extensions of notothyrial platform not joined to shell floor, supported by fulcral plates; brachiophore tops at right-angle junction of bases with fulcral plates. Median ridge low, broad, beginning at anterior edge of notothyrial platform and extending between impression of adductor muscles, merging anteriorly with impression of median interspace. Adductor muscle scars quadripartite, posterior pair shorter and wider than anterior pair. Mantle canal system saccate.

Ventral interior with short broad teeth; dental plates short, receding, dorsally convergent joined at their bases with margins of muscle field. Muscle field medially elongate pseudospondylium with oval outline, adductor track longer and thicker than diductor scars, width variable.

Discussion. This monotypic genus is erected for the species originally described as *Pleurorthis costatus* by Bates (1968, p. 169). The cardinalia of this species, however, are unlike those of *Pleurorthis* in that its brachiophore bases are obliquely set prolongations of the notothyrial platform, unattached to the shell floor but linked to the posterior shell wall by fulcral plates. The brachiophore bases of *Pleurorthis* are joined to the shell floor, and that genus lacks fulcral plates.

Although no currently recognized family accommodates *Ffynnonia*, it is probably more closely related to the Plectorthidae than any other. *Ffynnonia* is reminiscent of the eoorthids in its short notothyrial platform, but the eoorthids have laterally directed plates linking the brachiophores with the valve floor, no fulcral plates, and their folding is the reverse of *Ffynnonia*. The cardinalia of the Finkelnburgiidae are more like those of *Ffynnonia*, but the finkelnburgiids are differently shaped shells, with other internal differences such as their larger posterior adductor muscle scars in their dorsal valves, whereas in *Ffynnonia* the anterior pair is far larger. Fulcral plates characterize the Plectorthidae, but in this family brachiophore supports are joined to the shell floor. Other differences are to be seen in the ventral musculature, but in the dorsal adductor musculature, and in the folding of the shells there are similarities that suggest possible affinities.

Ffynnonia costata Bates, 1968

Plate 65, figs. 1–26

1968 *Pleurorthis costatus* Bates, p. 149.

Description. The additional specimens now available require emendation of the original species description. Subquadrate to semi-elliptical, cardinal extremities slightly extended, cardinal angles acute; sides subparallel to broadly rounded in posterior half, merging with broadly rounded anterior margin. Dorsal valve thickness about one-third its length; ventral valve thinner, about one-quarter its length. Dorsal fold and corresponding ventral sulcus originating at about one-tenth shell length, including angle of about 25°. Radial ornament

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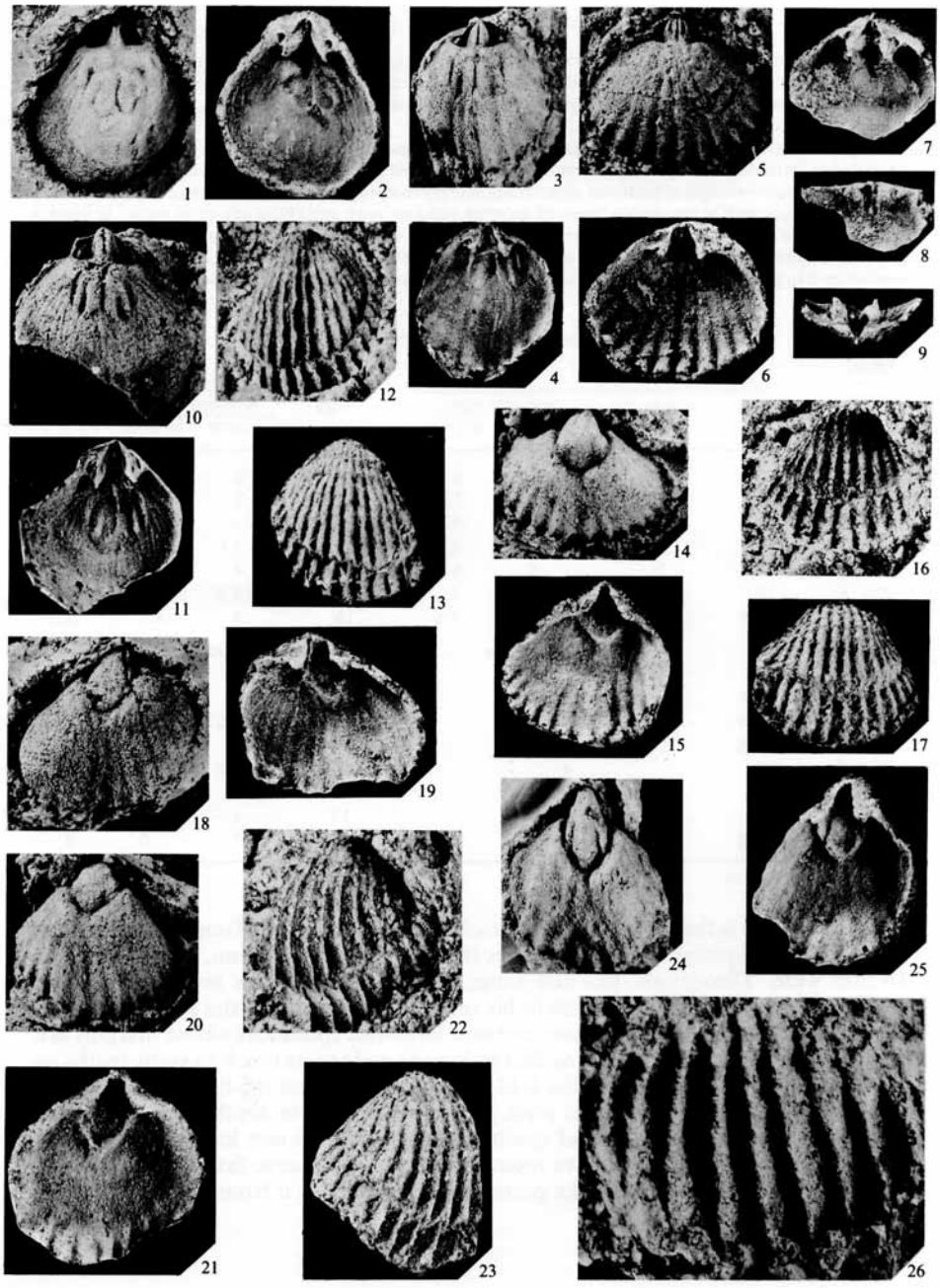
EXPLANATION OF PLATE 66

Figs. 1–26. *Rhynchorthis rotundus* Bates; figs. 1–4, 7–25 ×2, figs. 5–6 ×3, fig. 26 ×5; 1, 2, dorsal valve, BB73459, internal mould, internal replica; 3, 4, dorsal valve, BB73461, internal mould, internal replica; 5, 6, dorsal valve, BB73463, internal mould, internal replica; 7–9, dorsal valve BB73464, internal replica, normal view, tilted posteriorly to show stout brachiophore bases, posterior view; 10, 11, dorsal valve, BB73460, internal mould, internal replica; 12, 13, dorsal valve, BB73462, external mould, external replica; 14–17, ventral valve, BB73467, internal mould, internal replica; external mould, external replica; 18, 19, 26, ventral valve, BB73468, internal mould, internal replica, partial external mould showing detail of ornament; 20–23, ventral valve, BB73465, internal mould, internal replica, partial external mould, external replica; 24, 25, ventral valve, BB73466, internal mould, internal replica.



NEUMAN and BATES, early Ordovician brachiopods

fascicostellate, derived from about ten rounded primary costae, each expanding forward and dividing into two to four subordinate costellae; sulcus bears median costa for its entire length, fold a complementary interspace. Concentric ornament weakly developed; prominent, widely spaced growth lines preserved in a few specimens.

Internal features as described for genus, with following details noted: in dorsal valve cardinal process extends full length of notothyrial platform, lowest and thinnest posteriorly, becoming thickest and highest just behind anterior margin of platform, descending sharply to its termination at platform margin. Posterior adductor scar one-half to two-thirds length of anterior adductor scar, and about one-third wider. In ventral valve, adductor track width varies from about equal to that of each diductor scar to about twice their width. Anterior margin of pseudospondylium smoothly rounded either without median ridge, or with angular median prolongation and short median ridge. Pseudospondylium about three times longer than notothyrial platform.

TABLE 8. Measurements of *Ffynnonia costata* (Bates).

BB no.	Length				Width			Thickness
Dorsal valves	total	notothyrial platform	adductor scars posterior	adductor scars anterior	hinge	adductor scars posterior	adductor scars anterior	
				(mm)				
73469*	12.5	1.5	3	6	15	6	4.5	4
73470*	12.5	2	4	7.5	18.5	7	5.5	4
73471*	10	1.5	3	5.5	19	–	–	3
73472	8.5	1.5	2.5	3.5	15	3.5	5	2.5
73473*	11	1	3	5	14	4	5	2.5
73474*	10	1.5	2.5	4	14	3.5	4	4
73475	9.5	1	2	4.5	15	4	4	3.5
Ventral valves			pseudospondylium			adductor scar	diductor scar	
73476*	14.5		5.5		22.5	2	1	4
73477*	10.5		3.5		15	1.5	1	2.5
73478*	10.5		3.5		14.5	2	.5	2
73479	11		4		14	1.5	.5	2
73480*	12		3.5		17	1	1	3
73481	8		2.5		13	1	.5	2
73482	10.5		2.5		14	1	.5	3

*Figured specimens

Discussion. This is the most abundant brachiopod species in the Treiorwerth Formation at Ffynnon-y-mab. Specimens range in width from 6 to 22 mm, with most 12 to 16 mm wide. Throughout this size range their length averages seven-tenths their width, the ratio specified by Bates in his original description of the species, but the ratio of length to width of fourteen common large-size specimens whose margins are well defined varies from as little as half as long as wide to as much as eight-tenths as long as wide. The amplitude of the fold and sulcus is low on smaller specimens, but varies considerably among larger ones, the sulcus ranging in depth from 1 to 3 mm beneath the flanks at the front of specimens more than 10 mm long. Despite these variables, however, the distinctive internal features and coarse fascicostellate ornament set apart this species and the genus erected to contain it from all others known to us.

Family SKENIDIIDAE Kozlowski, 1929
Genus SKENIDIOIDES Schuchert and Cooper, 1931

Skenidioides sp. (1) Bates, 1968

Plate 64, figs. 12–23

1968 *Skenidioides* sp. (1) Bates, p. 156, pl. 5, figs. 1, 2.

Description. Small, ventribiconvex, transversely subquadrate to triangular, widest at hinge, about one-quarter greater than length, cardinal extremities acute, sides subparallel to anteriorly convergent, front broadly to narrowly rounded. Ventral valve about five times deeper than dorsal valve; interareas of similarly contrasting length, dorsal anacline, ventral apsacline, notothyrium and delthyrium open, unmodified. Dorsal beak low, merging with narrow sulcus that extends to anterior margin; flanks moderately swollen, maximum convexity at about midlength. Ventral valve pyramidal, maximum thickness at high, erect beak, anterior slope uniform, fold gentle. Radial ornament costate, about five well-developed costae on each flank, with two or more weaker ones in each posterior sector; ventral median costa and complementary dorsal interspace wider than costae of flanks; concentric ornament indistinct.

Dorsal interior with long, shallow, posteriorly sloping notothyrial platform, anteriorly elevated on median septum. Cardinal process thin, blade-like, extending entire length of platform. Brachiophore bases ventrally divergent at sides of platform, their tops sharply pointed. Sockets widely spaced, with thickened floors. Median septum high, extending nearly to anterior shell margin, its top about at commissural plane. Adductor muscle scars and mantle canal system not preserved; radial ornament expressed internally by undulations of shell floor.

TABLE 9. Measurements of *Skenidioides* sp. (1)

BB no.	Length			Width	Thickness	Costae
Dorsal valves	total	notothyrial platform	interarea			
			(mm)			
74071*	2.5	.5	.25	3	.25	10
74072	3.0	1.	.25	4	.5	–
74073	2.5	1.	–	4	.5	–
Ventral valves		spondylium				
74074*	2.5	1	1.5	4.5	1.5	10
74075	3	.75	1.5	4	2	10
74076	2.5	1	2	4	2	
74077*	2	1	1.5	4	1.5	

*Figured specimens

Ventral interior with shallow spondylium simplex posteriorly supported by median septum but unsupported anteriorly. Median septum low, short, variable, extending no more than half spondylium length, and to midlength of shell floor, reduced to virtual absence in some specimens. Teeth not well defined on available specimens; muscle scars and mantle canal system not seen. Radial ornament impressed as in dorsal valve.

Discussion. The coarse sandstone in which specimens of this species are preserved prohibits specific identification, as indicated by Bates (1968, p. 156). The few specimens preserving imprints of ornament suggest that this species differs from most others

of the genus in its unbranched costae and their small number. By contrast, *S. billingsi* Schuchert and Cooper, 1931 (Schuchert and Cooper 1932, p. 72), the type species of the genus, from the Rockland Formation of Ontario, Canada, has more than twice as many costellae, some of which branch and some are intercalated at about mid-length. Of the twelve species described by Cooper (1956, pp. 491–502) from the Middle Ordovician of North America, all have more ribs than the Treiorwerth species, and all show some degree of rib branching or intercalation. One of these species, *S. mediocostatus* Cooper (1956, pp. 496–497) from the Benbolt Formation of Cooper and Prouty (1943) in Virginia, resembles the Treiorwerth species in the broad median costa of its ventral valve, and the complementary wide interspace of its dorsal valve. The same feature is also seen in *Skenidioides* sp. (2) Bates (1968, pp. 156–157) from the Nantannog Formation (*bifidus* Zone) on Anglesey.

The Treiorwerth species is thus the oldest recorded for the genus. *Protoskenidioides* Williams (1974, p. 83), a monotypic genus based on *P. revelata* Williams (1974, p. 85) from the Arenig Mytton Flags of the Shelve inlier, was distinguished by the ontogeny of its cardinalia and the lobation of the anterior margin of its notothyrial platform (called brachiophore bases by Williams) of larger specimens. In that genus, moreover, the anterior margin of the platform is elevated above the median septum. In these respects the Treiorwerth species has more in common with *Skenidioides* than it does with *Protoskenidioides*.

Superfamily ENTELETACEA Waagen, 1884
Family PAURORTHIDAE Öpik, 1933
Genus PAURORTHIS Schuchert and Cooper, 1931

Paurorthis? sp.

Plate 64, figs. 24–38

Description. Small, ventribiconvex, tumid, transversely subelliptical, maximum width near midlength, about one-third greater than length. Dorsal interarea short, anacline; notothyrium open, unmodified. Dorsal beak low, maximum thickness at about one-third shell length, lateral and anterior slopes of nearly uniform, gently curvature, sulcus lacking or shallow. Ventral interarea apsacline, about three times longer than dorsal interarea; delthyrium open. Ventral beak high, profile somewhat more domed than dorsal valve. Radial ornament of rounded costellae slightly wider than interspaces. Costellae increase both in size and in number by branching and intercalation in middle third of shell; sixteen to eighteen costellae per 5 mm in the median sector of shell margin of larger individuals.

Dorsal interior with large notothyrial platform of thickened shell; cardinal process variably developed; in most specimens low, thin, occupying full length of platform; reduced to a low ridge in a few specimens (3; 10%). Brachiophore bases divergent, merging with concave surface of notothyrial platform, fulcral plates lacking, distal extensions of brachiophores short, terminations blunt. Shell thickened beneath socket floors and along posterior margin, diminishing laterally. Anterior margin of notothyrial platform thickened, merging medially with broad, low myophragm extending to about midlength of shell. Adductor muscles deeply impressed, quadripartite; posterior pair suboval, about half length of medially elongate, subtriangular anterior pair. Mantle canal system not seen; radial ornament impressed on shell interior around periphery.

Ventral interior with short, blunt teeth, short, advancing dental plates, bases extended nearly full length of subcordate muscle field. Diductor scar width each about equal to that of adductor track, adductor track thicker and slightly shorter than diductor scars. Mantle canal system not seen; radial ornament impressed as on dorsal valve.

TABLE 10. Measurements of *Paurorthis*? sp.

BB no.	Length			Width			Thickness	Costellae
Dorsal valves	total	notothyrial platform	myophragm	hinge	maximum at specified length	notothyrial platform		
				(mm)				(per 5mm)
73483*	5.5	1	3	7	8/2	2	1	16
73484*	6.0	1.5	3	8	9.5/4	2.5	1	–
73485*	6.0	1.5	3.5	7	8/3	2.5	1	–
73486*	5.0	1.5	3	7	8/3	2	1.25	–
73487	6.0	1.5	3	7	8/3	2	1	–
73488*	6.0	1.5	3	7	8/3	2	1	–
Ventral valves		muscle field				muscle field		
73489	6.5	2.5		6	7/3	2	1.75	–
73490*	6.5	2.5		6.5	7/3	2	1.75	18
73491*	5.5	2		6	7/2	2	1.5	–
73492*	5.0	1.5		6	8/1.5	1.75	1.5	–

* Figured specimens

Discussion. Identification of these specimens as an unnamed species of *Paurorthis* remains in doubt because the shell structure is unknown and the presence of punctae cannot be established. Shell exteriors and most internal features suggest this assignment, but inside the dorsal valve the notothyrial platform is exceptionally long for the genus.

Suborder CLITAMBONITIDINA Öpik, 1934
Superfamily CLITAMBONITACEA Winchell and Schuchert, 1893
Family POLYTOECHIIDAE Öpik, 1934
Genus TRITOECHIA Ulrich and Cooper, 1936

Tritoechia pyramidalis Bates, 1968

Plate 64, figs. 39–49

1968 *Antigonambonites pyramidalis* Bates, p. 163, pl. 6, figs. 12–18.
1968 *Tritoechia* sp. Bates, p. 161, pl. 6, figs. 1–3, 5.

Revised diagnosis. Medium to large *Tritoechia* with parvicostellate ornament of strongly contrasting costellae; median ridges in both valves variably developed.

Description. Medium to large for genus, subquadrate, subpyramidal, about one-third wider than long, widest at hinge or in posterior third; ventral valve about three times as deep as dorsal valve. Dorsal interarea anacline, short, with short chilidial plates. Dorsal beak low, maximum thickness at about one-quarter shell length; sulcus variable, low and broad in some specimens, weakly developed or absent in others. Ventral interarea length one-quarter to one-fifth hinge-width, steeply apsacline, with strongly arched pseudospondylium having large apical foramen; shell deepest near beak, lateral and anterior slopes broadly arched, fold obscurely defined. Parvicostellate ornament with stronger costellae 1–2 mm apart enclosing four to eight weaker ones over most of shell surface, more crowded posteriorly, increasing anteriorly by enlargement of weaker ones. Growth lamellae short, closely spaced, nearly uniform over entire shell surface.

Dorsal interior with very short, elevated notothyrial platform having variable median support, most commonly apical thickening shorter than platform, absent in some, rarely prolonged to median septum.

Cardinal process short, thick; brachiophores widely divergent ridges merging posterolaterally with shell floor, enclosing narrow sockets. Adductor muscle scars variably impressed, medially elongate, subtriangular, posterior partly flanking anterior pair. Mantle canal system not seen; ornament impressed on margins of some specimens.

Ventral interior with short, wide teeth; dental plates short, equal in height to length of interarea, erect, subparallel, their bases forming sides of muscle field. Delthyrial cavity deep, with pedicle callist having raised anterior margin. Muscle scars well differentiated, adductor track narrow, set somewhat higher than diductor scars, separated from them by low, subparallel ridges. Anterior margin of muscle field thickened, trilobed, diductor scars with angular anterolateral corners, somewhat longer than adductors. Low median ridge extending to midlength rarely present. Mantle canal system not preserved; ornament impressed as in dorsal valve.

TABLE 11. Measurements of *Tritoechia pyramidalis* (Bates).

BB no.	Length			Width			Thickness	Costellae	
Dorsal valves	total	notothyrial platform	inter-area	hinge	maximum at specified length	notothyrial platform		total strong	weak between strong
					(mm)				
73493	6	.5	.5	7	9/3	1	1.5	8	4-8
73494	5.5	.5	.5	8	–	1.5	.75	–	
73495	8	.5	.5	9	11/3	1.5	1	–	
Ventral valves		muscle field				muscle field			
73496	10	3	4	10(15)	–	3	4.5	11(14)	4-6
73497	7	2	2	10	–	1.25	2.5		

( )Estimate

Discussion. Classification of this species with *Tritoechia* rather than *Antigonambonites*, and inclusion of the unidentified Treiorwerth species of *Tritoechia* with it, is indicated after study of nearly 100 specimens. Ventral valves of these specimens do not confirm the presence of a spondylium triplex; instead the ventral muscle field approaches the form of a pseudospondylium, in front of which in a few specimens (three of forty-nine) there is a low, short, median ridge. The specimens bearing such a ridge are in every other respect like those lacking one. A short median ridge in front of the ventral muscle field is a common feature of *Tritoechia* (Ulrich and Cooper 1938, p. 160), but is lacking from many specimens assigned to the genus (e.g. *T. billingsi* Neuman, 1976, pl. 3, figs. 1, 3).

Parvicostellate ornament similar to that of *T. pyramidalis* characterizes eight of the other seventeen named species of *Tritoechia*, the others being more equally multicostellate. The contrast of stronger and weaker costellae is greatest in *T. pyramidalis*, and the number of subordinate costellae included between the stronger ones is larger than in other species.

Family CLITAMBONITIDAE Winchell and Schuchert, 1893
Subfamily ATELELASMATINAE Cooper, 1956
Genus ATELELASMA Cooper, 1956

Atelelasma sp.

Plate 68, figs. 12-16

1968 *Apomatella*(?) sp. Bates, p. 163, pl. 6, figs. 8-11.

Description. Ventribiconvex, subquadrate shells, wider than long, cardinal extremities obtuse, hinge width a little less than maximum width, slightly beyond midlength; front broadly rounded. Dorsal interarea short, anacline; notothyrium not seen. Ventral interarea very long, apsacline, delthyrium open, with slight marginal thickening. Dorsal valve of low convexity, deepest in posterior third; sulcus originating just beyond beak, including angle of about 35°, maximum depth at shell front about 1 mm below rounded crests of flanks. Ventral valve pyramidal in lateral profile, beak high, lateral and anterior slopes steep, fold less conspicuous than sulcus, anterior commissure sulcate. Radial ornament costellate, costellae of nearly uniform dimensions through shell length, about twelve per 5 mm, increasing in number at each growth lamella. Growth lamellae crenulated, crenulations corresponding with preceding costellae: lamellae of dorsal valve more closely spaced (about 0·5 mm intervals) than those of ventral valve.

Dorsal interior incompletely known, notothyrial platform not seen, inferred to be very short, elevated. Brachiophores widely divergent (about 150°), short, low. Adductor muscle scars quadripartite, shallow excavations with strong myophragm; posterior pair oval, smaller than elongate, subtriangular anterior pair. Mantle canal system not seen; internal impression of radial ornament confined to widely spaced marginal grooves.

Ventral interior with moderately deep spondylium simplex strongly elevated above shell floor; teeth not preserved. Median septum short, receding from beneath anterior margin of spondylium, merged with broad median thickening of posterior part of shell floor. Sides of spondylium slope steeply ventromedially, set off from broadly concave floor by pair of narrow gutter-like grooves, the latter possibly diductor muscle tracks. Mantle canal system not seen; impression of ornament not preserved.

TABLE 12. Measurements of *Atelelasma* sp.

BB no.	Length			Width			Thickness	Costae
Dorsal valves	total	adductor muscle scar	interarea	hinge	maximum at specified length	adductor muscle scar		
				(mm)				per 5mm
73499*	8	4	–	8(10)	12/5	4	–	–
73500	7(9)	–	–	8(12)	12(14)/5	–	2	2
Ventral valves		spondylium				spondylium		
73501*	10	4.5	6	16	17/7	2	4	13
73502	9	3	–	9	10/4	2	3	–

*Figured specimen, ( )Estimated measurement

Discussion. This species resembles *A. atlanticus* Neuman (1976, pp. 24–25, pl. 3, figs. 6–23) from the Summerford Group, Newfoundland, the only other *Atelelasma* having growth lamellae throughout the full length of the shell. That species, however, is widest at the hinge and has acute cardinal extremities, whereas the maximum width of the Bod Deiniol species appears to be near its midlength. Differences in their radial ornament also distinguish the two species, *A. atlanticus* having two orders of costellae whereas only one is recognizable on the Bod Deiniol species.

Superfamily GONAMBONITACEA Schuchert and Cooper, 1931
Family GONAMBONITIDAE Schuchert and Cooper, 1931
Genus ANTIGONAMBONITES Öpik, 1934

Antigonambonites sp.

Plate 68, figs. 25–26

Description. Single dorsal valve apparently abraded; part preserved includes posteromedial portion, length preserved (7 mm) about half original length, and two-thirds original width (7 mm preserved); original

outline unknown. Convexity low, interarea short (1 mm), notothyrial platform short (1 mm) with anterior margin lifted above shell floor, supported by low, broad median ridge; cardinal process lacking; brachiophores not preserved. Shell floor with laterally directed shelf-like plates, probably attachments of posterior adductor muscles; median ridge in front of these plates thin, septum-like, flanked by pair of strong, radially disposed ridges enclosing depressions, probably anterior muscle scars, each divided by low ridge.

Single ventral valve includes nearly full length of interarea (9 mm), probably less than half shell length (12 mm preserved), about half shell width (13 mm preserved). Hemipyramidal lateral profile inferred, with interarea length nearly half estimated full shell length (20 mm). Teeth not preserved, presence of pseudodeltidium questionable. Delthyrial chamber deep, occupied by hemiconical spondylium triplex with concave sides and narrow medial groove. Anterior margin of spondylium elevated well above shell floor; supporting plates largely obscured by shell tissue beneath spondylium, median plate thick with very short prolongation on to shell floor; lateral plates about equal in length to median plate, but much thinner. Radial ridges and furrows of *vascula genitalia* impressed on posterolateral part of shell floor.

Discussion. The two available internal moulds are classified together as the opposite valves of an undetermined species of *Antigonambonites* because each possesses several characteristics peculiar to that genus. Nevertheless, neither is accompanied by an external mould preserving ornament that ordinarily permits confirmation of the association of such disarticulated valves. These specimens particularly resemble two of several from the Summerford Group, Newfoundland (Neuman 1976, pl. 4, figs. 20, 24) that were assigned to this genus.

Order STROPHOMENIDA Öpik, 1934
Suborder STROPHOMENIDINA Öpik, 1934
Superfamily PLECTAMBONITACEA Jones, 1928
Family TAFFIIDAE Ulrich and Cooper, 1936
Genus TAFFIA Ulrich *in* Butts, 1926

Taffia? sp.

Plate 68, figs. 27–29

Description (ventral valve only). Moderately convex, wider than long, semi-elliptical, length about two-thirds hinge-width, widest at hinge, cardinal extremities acute, sides moderately convergent (about 20°), merging with broadly rounded front at about two-thirds shell length. Interarea moderately long, gently apsacline; delthyrium wide (about 80°), with moderately arched pseudodeltidium covering its apical third; no foramen observed. Lateral profile of low convexity in posterior two-thirds, with increased convexity anteriorly; maximum thickness at about two-thirds shell length. Anterior profile uniformly convex, rectimarginate. Ornament poorly preserved, about five widely spaced fine costellae per 5 mm at front of large specimens. Concentric ornament not seen.

Interior with wide, short teeth, dental plates sharply receding, erect. Delthyrial cavity moderately deep, muscle field subtriangular, with broadly rounded thickened anterior margin at about one-quarter shell length; boundaries between adductor and diductor scars not seen. Mantle canal system saccate, *vascula media* extending anteriorly from muscle field, separated by groove in middle third of shell floor, before diverging in broad arc parallel to shell margin. Marginal crenulations 1–2 mm long at about 1 mm spacing anterolaterally.

TABLE 13. Measurements of *Taffia*? sp.

BB no.	Length			Width		Thickness
Ventral valves	total	muscle field	interarea	hinge	muscle field	
			(mm)			
73505*	13	3.5	3	15(19)	4	2.5
73506	11	3	3	15	3	3

*Figured specimen, ( )Estimated measurement

Discussion. Generic identification of these shells remains questionable in the absence of dorsal valves. These ventral valves, however, are like those of *T. planoconvexa* Butts (Ulrich and Cooper 1938, p. 181, pl. 37, figs. 12, 13, 16, 17) from the Odenville Limestone, Alabama, and *Taffia*? sp. from the Summerford Group, Newfoundland (Neuman 1976, pp. 34–35, pl. 7, figs. 16–21), both of late Arenig age. The presence of twenty-one ventral valves of the latter, compared to one dorsal valve indicates similarity in the post-mortem history of that species to the one in the Bod Deiniol Formation.

Order PENTAMERIDA Schuchert and Cooper, 1931
Suborder SYNTROPHIDINA Ulrich and Cooper, 1936
Superfamily PORAMBONITACEA Davidson, 1853
Family HUENELLIDAE Schuchert and Cooper, 1931
Subfamily RECTOTROPHIINAE Bates, 1968
Genus RECTOTROPHIA Bates, 1968

Rectotrophia globularis Bates, 1968

Plate 67, figs. 19–30

1968 *Rectotrophia globularis* Bates, p. 176, pl. 10, figs. 11–17.

Description. Small, syntrophoid, subcircular in outline, subequally biconvex, with low dorsal fold and complementary ventral sulcus. Generally wider than long, ranging from width one-quarter greater than length to slightly longer than wide. Maximum width at about midlength, sides diverging from apex at about 100°, broadly rounded at midlength, front nearly straight, that of dorsal valve slightly extended at fold, that of ventral valve similarly recessed at sulcus. Interareas short, that of dorsal valve orthocline, slightly shorter than apsacline ventral interarea; delthyrium and notothyrium open. Lateral commissure straight, anterior commissure episulcate. Dorsal valve lateral profile of nearly uniform convexity from subrostrate beak to anterior margin; transverse profile behind midlength moderately domed, steepened abruptly toward posterolateral sides; anterolateral slopes lack marginal steepening in anterior half. Low fold bearing two wave-like costae variably developed, prominent in some specimens and extending to midlength, confined to shell front in some, and imperceptible in a few. Ventral valve lateral profile a little less convex than dorsal valve; low, wide sulcus extends forward from midlength of most specimens, flanks moderately inflated, posterolateral sides steeply sloping; sulcus with three wave-like costae at front margin. Ornament of closely spaced, nonimbricating growth lines, stronger than very fine, barely visible radial striations.

Dorsal interior with steep-sided notothyrial cavity containing notothyrial platform of slightly thickened shell, its anterior margin a low transverse ridge. Platform length and width about equal, one-fifth to one-quarter shell length. Cardinal process rudimentary, a very low ridge traversing length of platform. Brachiophores imperfectly preserved, presumably anteriorly directed, blade-like. Supporting plates strong, nearly vertical, with subparallel bases slightly convergent forward, extending to anterior margin of notothyrial platform. Adductor scars well impressed, each scar longer than wide, longest adjacent to low myophragm. Mantle canal system not seen.

Ventral interior incompletely known; teeth not preserved, dental plates strong, high, erect, with anterior edges receding from beneath interarea to midheight, then advancing to form posterior half of sides of muscle field. Muscle field an elongate pseudospondylium, one-third to one-half shell length, with sides subparallel or slightly anteriorly convergent, front narrowly rounded. Muscle scars not differentiable, pseudospondylium floor in best preserved specimens having closely spaced fine lines parallel to its anterolateral margins. Mantle canal system not preserved.

Discussion. The nearly fifty specimens of this species in the present collection include both internal and external moulds of both valves and thus permit significant emendations of the original description of the species which was based on a few internal

TABLE 14. Measurements of *Rectotrophia globularis* Bates.

BB no.	Length				Width				Thickness
Dorsal valves	total	notothyrial platform	adductor muscle scars	inter-area	hinge	maximum at specified length	notothyrial platform	adductor muscle scars	
IGS no.	(mm)								
Af.1436(h)	6.7	.6	2.6	–	–	7/5	1	2.6	2.8
Af.1436(p)	5.2	1.1	2.2	–	–	5(6.7)/3.3	1.4	2.0	2.4
Af.1442(p)	6.7	1.4	3.0	–	–	5.7(6)/4	1.3	1.9	–
BBno.									
73507*	7.5	2	4	1.5	6	9/5	2	3.5	1.5
73508	5.5	2	–	–	4	6/3.5	1.5	2.5	2
73509	7	1.5	4.5	–	5(6)	8.5/4.5	1.5	2.5	1.5
73510*	5(6)	1.5	4	.75	5	6.5/4	1.5	2	1.5
73511	7	1.5	5	1.5	5	8/6	1.5	3	2.5
73512*	6	1.5	3.5	1	5	8/4	2	3	2
Ventral valves		pseudospondylium					pseudospondylium		
73513	8	4		–	7	10/5	4		2
73514	6.5	3		1.5	6	7/3	2		1.5
73515	7	2.5		–	4	8/5	2.5		2
73516*	9	4		–	–	8/5	–		2
73517*	7	3.5		–	7	9/5	2.5		2
73518	5	3		–	5	6.5/3.5	2		1.5
73519*	5.5	1.5		–	3.5	5/4	1.5		1.5

(h)Holotype, (p)Paratype,* Figured specimen, ( ) Estimated measurement

moulds. External moulds of both valves indicate that it has a combination of syntrophid and camerellid features; the posterior parts, especially the well-developed interareas, are like those of syntrophids; the anteriors, especially the episulcate anterior commissure, are like some camerellids. The shell is ornamented by very fine radial striations and more conspicuous growth lines except near the front where there are wavelike costae confined to the dorsal fold and ventral sulcus.

EXPLANATION OF PLATE 67

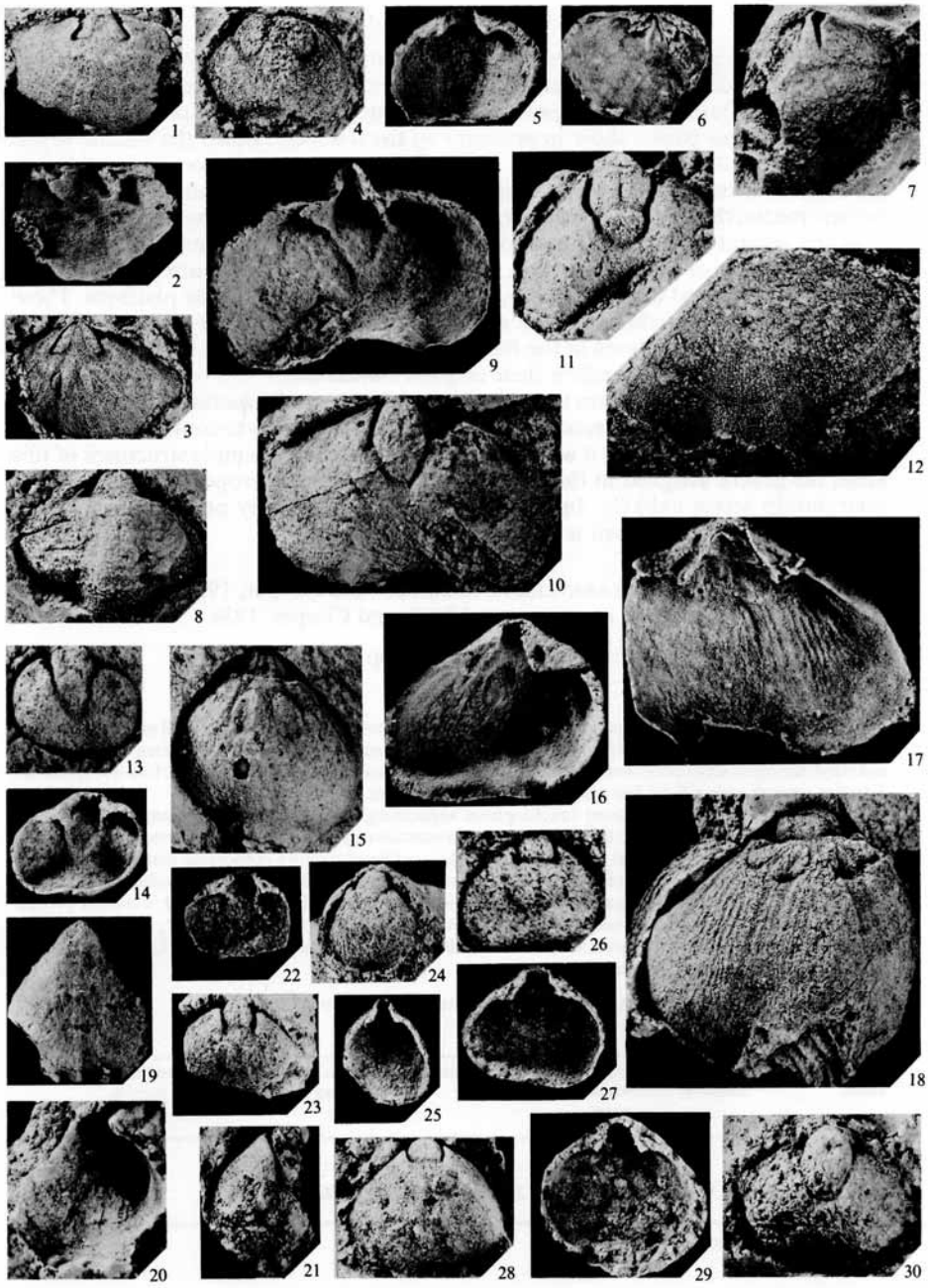
Figs. 1–3. *Diaphelasma*? sp., ×1·5; 1, 2, dorsal valve, BB73521, internal mould, internal replica; 3, dorsal valve, BB73520, internal mould.

Figs. 6, 7. Porambonitid gen. *et* sp. indet., ×1·5; dorsal valve, BB73531, internal replica, internal mould.

Figs. 4, 5, 11, 13, 14. *Rugostrophia*? sp. 4, 5, dorsal valve, BB73528, internal mould, internal replica, ×2; 11, ventral valve, BB73530, internal mould, ×3; 13, 14, ventral valve, BB73529, internal mould, internal replica, ×2.

Figs. 9, 10, 12, 15–18. *Rugostrophia* sp., ×1·5; 9, 10, ventral valve, BB73526, internal replica, internal mould; 12, ventral valve, BB73527, external mould; 15, 16, dorsal valve, BB73525, internal mould, internal replica; 17, 18, dorsal valve, BB73522, internal replica, internal mould.

Figs. 19–30. *Rectotrophia globularis* Bates, ×3; 19–21, ventral valve, BB73516, external replica, external mould, partial internal mould; 22, 23, dorsal valve, BB73510, internal replica, internal mould; 24, 25, ventral valve, BB73519, internal mould, internal replica; 26, 27, dorsal valve, BB73512, internal mould, internal replica; 28, 29, dorsal valve, BB73507, internal mould, internal replica; 30, ventral valve, BB73517, internal mould.



NEUMAN and BATES, early Ordovician brachiopods

The holotype of the species designated and illustrated by Bates (1968, p. 177, pl. 10, figs. 14, 15) is a dorsal valve rather than a ventral valve as was indicated. It, in common with the two illustrated paratypes identified as dorsal valves and the dorsal valves illustrated in this paper, show impressions of the low ridge down the middle of the notothyrial platform, here identified as a rudimentary cardinal process; in addition, all these specimens preserve the impressions of the adductor muscle scars in the posteromedial third of the valve floor, and the weak myophragm that separates them.

In the ventral valve the pseudospondylium is nearly twice the length of the notothyrial platform of the dorsal valve, and its anterior margin is more thickened and more broadly curved than the low transverse ridge at the front of the platform. These internal features, together with the shallow sulcus, clearly identify these as ventral valves, and the crenulations at the front of the sulcus correspond with those on the folds of dorsal valves to confirm their original association.

These observations confirm the simplicity of the internal structures of this species, and further justify Bates's erection of a new genus and subfamily to contain it. Although the Huenellidae with which it was placed is characterized by simple structures of this kind, the genera assigned to this family have such different proportions that a close relationship seems unlikely. In the absence of other similarly proportioned forms, however, Bates's assignment is retained for convenience.

Family CLARKELLIDAE Schuchert and Cooper, 1931
Genus DIAPHELASMA Ulrich and Cooper, 1936

Diaphelasma? sp.

Plate 67, figs. 1–3

Description. No ventral valves available. Incomplete dorsal valves moderately large; shell outline unknown, probably transversely oval, wider than long, hinge-width less than maximum width. Interarea long, anacline; notothyrium open. Convexity moderate, uniformly domed in lateral and anterior profile, fold not apparent. Exterior smooth except for a few weak growth lines near front.

Interior with stout, widely flared brachiophore supporting plates, strongly divergent at their bases; anterior margins advancing from their pointed tops to anterior edge of diductor muscle scars. Fulcral plates present, forming shelf-like socket floors between midpart of brachiophore supporting plates and posterior shell wall. Notothyrial platform of slightly thickened shell, triangular, divided into three subequal triangular parts, with diductor muscle scars forming outer thirds impressed below middle third; cardinal process absent. Adductor muscle scars weakly impressed, outlines vague, probably triangular, bilobed, anterior margins at about midlength of preserved part of shell floor. Mantle canal system indistinct; radial ridges and furrows on shell floor suggest pinnate pattern.

TABLE 15. Measurements of *Diaphelasma*? sp.

BB no.	Length				Width				Thickness
Dorsal valves	total	notothyrial platform	adductor muscle scars	interarea	hinge	maximum at specified length	notothyrial platform	adductor muscle scars	
	(mm)								
73520	14	4	8	–	14(16)	16(20)/10	5	8	2
73521	13	3.5	7	2	16(20)	16(19)/8	5	9	2.5

( ) Estimated measurement

Discussion. These dorsal valves resemble those of *Diaphelasma breviseptatum* Ulrich and Cooper (1936, p. 629; 1938, pp. 224–225, pl. 48, figs. 24, 26, 27) from Lower Ordovician sandstone in Vermont (Luke Hill Formation of McGerrigle 1931) whose brachiophore supporting plates are longer relative to the total shell length than those of other species of the genus but which lack fulcral plates. Like other described species of the genus, *D. breviseptatum* has a strong fold which is not present on the Treiorwerth specimens. Identification of these specimens as a species of *Diaphelasma* cannot be confirmed, however, without knowledge of its ventral valve.

Family PORAMBONITIDAE Davidson, 1853
Genus RUGOSTROPHIA Neuman, 1971, emend. Neuman, 1976

1971 *Rugostrophia* Neuman, p. 118.
1971 *Cuparius* Ross, p. 125.
1976 *Rugostrophia* Neuman, p. 40.

Revised diagnosis. Porambonitid with reticulate ornament; brachiophore bases short, discrete or dorsally convergent, fulcral plates present, cardinal process absent; pseudospondylium with adductor scar in front of diductor scars.

Discussion. The second revision of the diagnosis of this genus is demanded by reappraisal of species previously assigned to it in the light of knowledge obtained from specimens of the unnamed species from the Treiorwerth Formation, described below. Previous statements concerning the location of muscle scars in ventral valves are in error, as is the reconstruction published in 1971 (Neuman 1971, fig. 3B). The Treiorwerth Formation specimens show these scars plainly, and knowledge gained from them indicates that the muscle scars in specimens of *R. sylvestris* and *R. latireticulata* had been misinterpreted.

The location of adductor scars in front of the diductors is a characteristic of some, but not all, porambonitids, the interiors of many of which are not known at all. Such is the arrangement in species whose interiors are best known, *Porambonites* (*Equirostra*) *schmidti* Noetling, 1883, and *P.* (*E.*) *baueri* Noetling, 1883, although Schuchert and Cooper (1932) characterized the ventral musculature of *Porambonites* otherwise, stating (p. 102): 'The adductor scars occupy a linear track between the diductor impressions.'

The unifying characteristic of the dorsal valve of *Rugostrophia* is its short brachiophore supporting plates whose degree of convergence and the consequent configuration of the notothyrial platform vary from species to species. The convergence is greatest on the Treiorwerth species in which the bases of these plates converge near the middle of the valve, and the anterolateral margins of their notothyrial platforms are elevated above the shell floor for about half the width of the platform. The convergence is least in *R. latireticulata* and *R. cardilatus* whose notothyrial platforms are ankylosed to the shell floors throughout their entire width. *R. sylvestris* displays an intermediate condition, its notothyrial platform lifted above the shell floor only at its outer extremities.

Cuparius Ross is placed in synonomy with *Rugostrophia* because they have essentially identical internal characteristics. The ventral interior of *Cuparius* was stated to be the same as that of *Syntrophopsis* with a reduced median septum; examination of the

relevant paratype of *R.* (= *C.*) *cardilatus* (Ross, 1971) shows that its dental plates are discrete rather than united above the shell floor as they are in *Syntrophopsis*. Study of the paratype of *R.* (= *C.*) *cardilatus* displaying the interior of the dorsal valve shows that the brachiophore supporting plates descend to the shell floor rather than converging as they do in *Syntrophopsis*.

Because assignment to *Rugostrophia* depends on internal characteristics, the only previously described species assigned by Ross to *Cuparius* that is here assigned to *Rugostrophia* is '*Porambonites*?' sp. 3 of Cooper 1956 (p. 610). Generic assignment of the following is uncertain: '*Syntrophopsis*?' *landmani* Ulrich and Cooper, 1938 (p. 234); '*S.*?' *vetusta* Ulrich and Cooper, 1938 (p. 239); '*Porambonites*?' sp. 1 Cooper, 1956 (p. 609); '*P.*?' sp. 2 Cooper, 1956 (p. 610). '*P.*?' *umbonatus* Cooper, 1956 (p. 609) is excluded from *Rugostrophia* because in its ventral valve the adductor muscle scars form a linear track between the diductor scars.

Rugostrophia sp.

Plate 67, figs. 9, 10, 12, 15–18

1968 *Porambonites* (s.s.) sp. Bates, p. 177, pl. 11, figs. 3–6, 8, *non* figs. 1, 2.

Description. Large, inflated, ellipsoidal, dorsibiconvex, wider than long, with pronounced dorsal fold and corresponding ventral sulcus. Maximum width at about two-thirds shell length, about one-third greater than hinge width. Posterolateral sides diverging at obtuse angle (about 125°), merging with broadly rounded lateral extremities; front margin nearly straight. Dorsal interarea orthocline, about one-fifth shell length, notothyrium open; ventral interarea somewhat longer, apsacline, delthyrium open. Beaks of both valves high; that of dorsal valve subrostrate. Dorsal fold originating at beak, becoming well developed at about one-third shell length, with sides diverging at 20–25°, height at front of specimens 16–18 mm long about 5 mm above lateral commissure, higher in larger specimens; flanks swollen, slopes increasing laterally. Ventral sulcus shallow to midlength, then deepening progressively to complement dorsal fold; flanks swollen as on dorsal valve. Ornament poorly preserved, formed of moderately fine, closely spaced costellae and growth lamellae of similar strength and spacing, intersecting to form rows of equidimensional pits, about eighteen per 5 mm at front of large valves near their middle.

Dorsal interior with deep notothyrial cavity with dorsally divergent sides; notothyrial platform broadly concave, equilaterally triangular in outline, front slightly lifted above shell floor except in middle, divided into four subequal triangular parts; middle parts of thickened shell, probably seat of diductor muscles, separated by very low, indistinct median ridge; distinct cardinal process lacking. Brachiophore supporting plates dorsally divergent extensions of sides of notothyrial platform, very short, with little or no extent on

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EXPLANATION OF PLATE 68

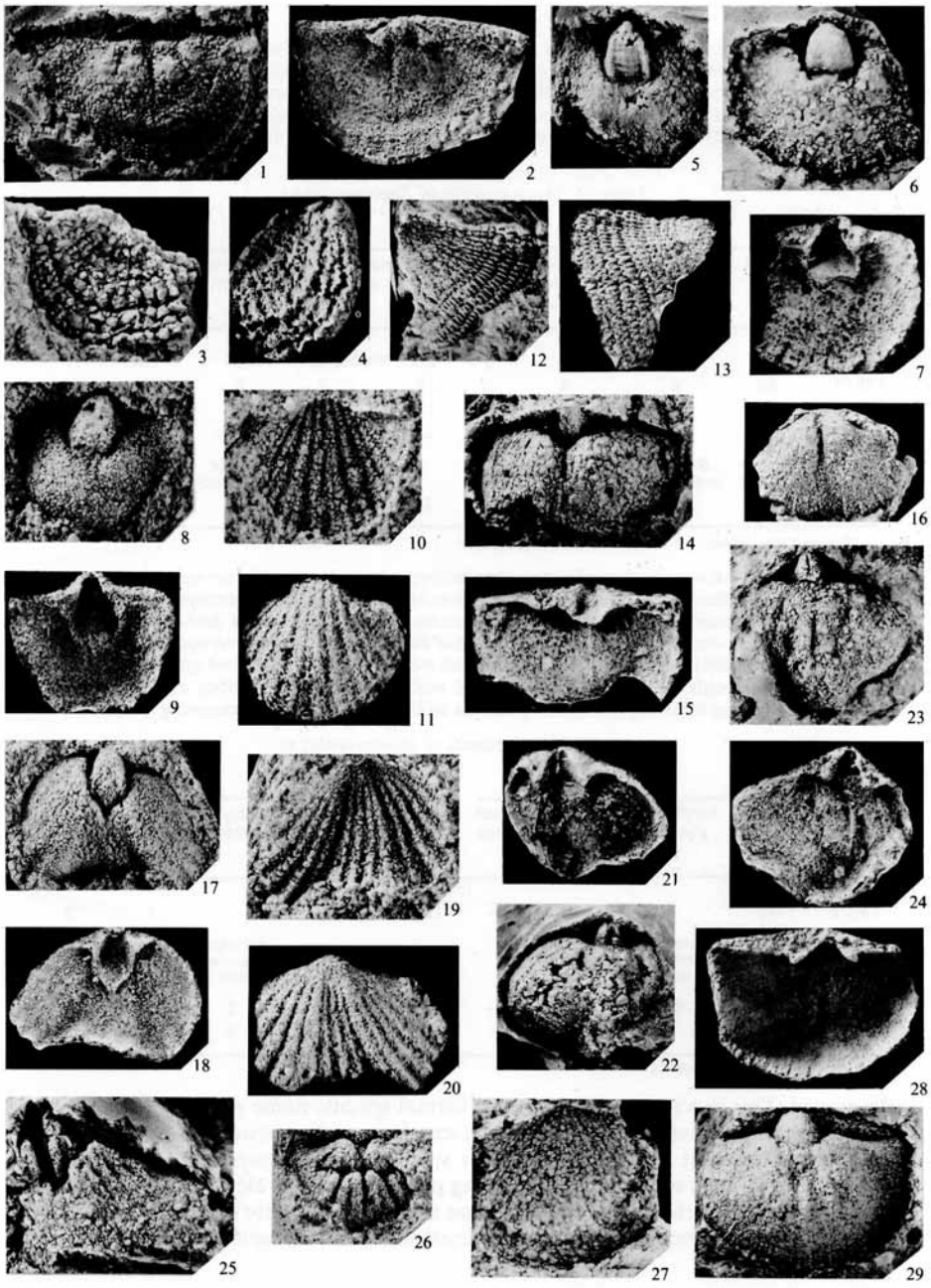
Figs. 1–11. *Productorthis* sp., ×3; 1–4, dorsal valve, BB73451, internal mould, internal replica, partial external mould, external replica; 5, ventral valve, BB73453, internal mould; 6, 7, ventral valve, BB73452, internal mould, internal replica; 8–11, ventral valve, BB73454, internal mould, internal replica, external mould, external replica.

Figs. 12–16. *Atelelasma* sp., ×2; 12–15, ventral valve, BB73501, partial external mould, external replica, internal mould, internal replica; 16, dorsal valve, BB73499, internal mould.

Figs. 17–24. *Platystrophia*? sp., ×2; 17–20, ventral valve, BB73457, internal mould, internal replica, external mould, external replica; 21, 22, dorsal valve, BB73456, internal replica, internal mould; 23, 24, dorsal valve, BB73455, internal mould, internal replica.

Figs. 25, 26. *Antigonambonites* sp., ×2; 25, ventral valve, BB73504, internal mould; 26, dorsal valve, BB73503, external mould.

Figs. 27–29. *Taffia*? sp., ×2; ventral valve, BB73505, external mould, internal replica, internal mould.



NEUMAN and BATES, early Ordovician brachiopods

to shell floor; tops sharply pointed. Fulcral plates strong, well elevated above shell floor. Adductor muscle scars large, quadripartite, margins thickened; posterior pair smaller, more widely spaced than anterior pair, both drop-shaped, anteriorly expanding. Mantle canal system pinnate; *vascula media* extending forward from anterior margins of anterior adductor scars along sides of fold without branching through most of shell length, flanked by somewhat narrower radially disposed ridges and furrows of *vascula myaria* and *genitalia*.

TABLE 16. Measurements of *Rugostrophia* sp.

BB no.	Length				Width				Thickness
Dorsal valves	total	notothyrial platform	adductor muscle scars	inter-area	hinge	maximum at specified length	notothyrial platform	adductor muscle scars	
				(mm)					
73522*	29	6	10	5	25	30(40)/20	7	14	10
73523	16	4	8	3	12	20/9	5	12	5
73524	18	4	–	–	15	22/12	5	–	6
73525*	21	5	10	5	17	23/15	4	8	6
Ventral valve		diductor muscle scar	adductor muscle scar				diductor muscle scar	adductor muscle scar	
73526*	21	7	10	–	20	31/12	8	12	6

*Figured specimens, ( )Estimated measurement

Ventral interior with stout teeth, moderately deep delthyrial cavity bounded by strong dental plates, erect at midheight, widely flaring near tops. Pseudospondylium low, extending beyond delthyrial cavity; diductor scars elongate, separated by faint median ridge, laterally bounded by bases of dental plates; adductor muscle scar shallow, circular, about two-thirds length of diductor scars, anterior to both dental plates and diductor scars, with thickened anterior margin. Median ridge lacking. Mantle canal system not preserved.

Three internal moulds, about half the length and width of specimens described above, with similar internal structures, are identified as *Rugostrophia*? for lack of external moulds preserving ornament.

TABLE 17. Measurements of *Rugostrophia*? sp.

BB no.	Length				Width				Thickness
Dorsal valve	total	notothyrial platform	adductor muscle scars	inter-area	hinge	maximum at specified width	notothyrial platform	adductor muscle scars	
				(mm)					
73528	10	1	5	–	10	12/7	–	7	3
Ventral valves		diductor muscle scar	adductor muscle scar				diductor muscle scar	adductor muscle scar	
73529	8(9)	1.5(2.5)	5(6)	–	10	11/5	3	2.5	2
73530	10	3	5	–	9	8(12)/6	3	2	3

( )Estimated measurements

Discussion. This species is not assigned a formal specific name pending the recovery of additional specimens that would permit satisfactory diagnosis. Presently available specimens show that it differs from other species of *Rugostrophia* in the degree of convergence of its brachiophore supporting plates, in the low elevation of its pseudospondylium, and in the absence of a median ridge. Its reticulate ornament is of intermediate coarseness between that of *R. latireticulata* and *R. cardilatus*.

Porambonitid gen. et sp. indet.

Plate 67, figs. 6, 7

1968 *Porambonites* (s.s.) sp. Bates (*pars.*), p. 177, pl. 11, figs. 1, 2.

Description. The single dorsal valve is incomplete, laterally compressed. Outline subcircular, apical angle obtuse, about 135°, maximum width (19 mm) at about midlength, about equal to length (20 mm); sides and front broadly rounded. Lateral profile highly convex in posterior half, beak prominent, maximum depth (5 mm) near middle with more uniform slope anteriorly. Anterior profile with low, narrow fold through all but posterior quarter, flanks moderately swollen, with increasing convexity laterally. Ornament not preserved.

Interior with deep notothyrial cavity bordered by closely spaced, stout, narrowly divergent brachiophore bases supporting widely flared, sharply pointed brachiophores having concave inner surfaces. Fulcral plates highly elevated. Notothyrial platform not differentiated, cardinal process absent. Brachiophore bases extend into shell floor to about one-quarter shell length. Adductor muscle scars shallow oval excavations outside brachiophore supporting plates, extending slightly beyond them. Mantle canal system poorly preserved, strips of shell callus anterior to anterior termination of brachiophore bases along sides of internal impression of fold, presumably *vascula media*.

Discussion. The absence of a ventral valve that can be confidently linked to the dorsal valve described here precludes positive generic identification. Internal features of this specimen are reasonably well displayed in the available internal mould and the rubber replica made from it, but the associated external mould preserves no details of its ornament. A single specimen from the Summerford Group, Newfoundland (Neuman 1976, p. 42, pl. 7, figs. 9–12) has essentially identical internal features preserved in its internal mould, and the imprint of finely reticulate porambonitid ornament in its external mould; this may have been the ornament pattern of the Treiorwerth specimen. Both specimens are of interest with regard to porambonitid taxonomy for their clear lack of a cardinal process and the anterior elongation of their brachiphore bases. The latter feature distinguishes them from the species of *Rugostrophia* with which they are associated.

The specimen illustrated by Bates (1968, pl. 11, figs. 1, 2; BB30598a) appears to be a dorsal valve, conspecific with the one described here but less complete and more deformed.

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