CARBONIFEROUS (VISEAN TO MOSCOVIAN)

BRACHIOPODS

FROM YUKON TERRITORY, CANADA

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Summary

Brachiopods are described from the Hart River, Wahoo and Blackie Formations of the Yukon Territory. The Hart River brachiopods are of upper Visean age, and the largest fauna from the overlying lower Blackie Formation in the Peel River area is judged to be Bashkirian. Faunas from the upper Blackie Formation and the basal Ettrain Formation at Tatonduk River and Cathedral Rocks, as well as Wahoo Formation of the Lisburne Group in northern Yukon Territory are possibly as young as Moscovian. The faunas are each distinctive, and are assigned to three different biozones.

The successive faunas show change in affinities through time. Whereas the Hart River faunas like those of the United States, the younger two faunas have developed distinctive traits, with some genera limited to northwest Canada, and some genera that appeared in the Carboniferous record for Canada later flourished under cool to cold conditions of eastern Australia and New Zealand during Permian time.

New genera: *Rhynchoporusia, Hartea, Muirwoodiciana, Mysteronia* and *Papulifera.*

New species: "*Kutorginella" primigenius, Flexaria echinata, Rhynchoporusia multiplicata, Mysteronia mysticus, Hartea venustus, Buxtonia sulcata, Levipustula canadensis, Muirwoodiciana inexpectans, Rhynchopora mysteronia, Deltachania elongata, Papulifera plana, Saltospirifer gibberosus, Protoanidanthus monstratus, Rhipidomella borealis, Composita largitas* and *Rorespirifer prodigium.*

New family group name: Campbelliconchinae.

International Period	Stage	Yukon Formation	Biozone	Member
LOWER PERMIAN	Artinskian	Tahkandit		
		Jungle Creek	*Jakutoproductus verchoyanicus*	
	Sakmarian		*Ogilviecoelia inflata*	
			"Harkeria transversa"	Member F
	Asselian		*Ogilviecoelia shii*	Member E
			Rugivestigia commarginalis	Member D
			Kochiproductus imperiosus	Member C
			Ogilviecoelia initiatus	Member B
UPPER CARBONIFEROUS	Gzhelian		*Septospirifer tatondukensis*	Member A
	Kasimovian	Ettrain		
	Moscovian	Blackie	*Rorespirifer prodigium*	
	Bashkirian		*Buxtonia sulcata*	
	Serpukhovian	Hart River	(palynomorphs)	
	Visean		*Quadralosia delicata*	

Table 1. Summary of Carboniferous and Permian formations and biozones in the Ogilvie Mountains of Yukon Territory. The *Rorespirifer prodigium* Zone is found in the Wahoo Formation, Blackie Formation and basal Ettrain Formation of the Ogilvie Mountains but not in Ettrain equivalents of Peel River. Table not to scale.

Contents (new taxa in bold)

INTRODUCTION

The Carboniferous rocks and faunas mapped by Operation Porcupine in the northern and western Yukon Territory of Canada (Norris 1997) commenced with Ford Lake Formation, the upper part dated as Visean (Lower Carboniferous), and this is overlain by the Hart River Formation, named by Bamber in Bamber & Waterhouse (1971) and dated as late Lower Carboniferous, or uppermost Mississippian Subsystem. The Hart River brachiopods are part of world-wide assemblages, and are particularly close in their make-up to those of the Moorefield Formation of Arkansas, as described by Girty (1911), although much poorer in the number of genera. The Hart River fossils are correlated with the Chesterian Stage of the United States, and judged to be late Visean, with Serpukhovian palynomorphs at the top.

Overlying macro-fossils, dominated by brachiopods, developed distinctive aspects indicative of an Arctic Canadian province. The oldest fauna, described from the Blackie Formation as discrimated by Pugh (1983), and coming immediately above the Hart River beds, is correlated with the Bashkirian Stage, equivalent to Morrowan of United States and upper Namurian of Europe. It contains distinctive Productida, and even shares genera with the Carboniferous of Argentina, pointing to the development of climatic realms in response to severe bipolar cooling. A number of genera are found in common with Arctic Russia.

Faunas of the overlying brachiopod zone are also distinctive, retaining Arctic attributes, and including a member of the martiniidin superfamily Ingelarelloidea, which characterized cold-water faunas of Russia and especially east Australia and New Zealand during Permian time. The fauna has been dated as Moscovian (Atokan, Westpalian) by small Foraminifera, but differs from the much larger late Bashkirian or early Moscovian fauna described by Carter & Poletaev (1998) from Ellesmere Island, though it does share some generic similarities. It is found widely in the Yukon Territory, in the upper Blackie Formation and lower Ettrain Formation in the Tatonduk River and Cathedral Rocks, and the Wahoo Formation of the northern part of the territory (Bamber & Waterhouse 1971), a unit extended from its type outcrops in Alaska.

Brachiopods of these formations and biozones are described in the following study. The study builds on initial reports provided by the writer to the Institute of Petroleum and Sedimentary Geology, Geological Survey of Canada, at Calgary (Waterhouse 1968c, d) and

the faunal analyses in Bamber & Waterhouse (1971). Compared with faunas of the overlying Ettrain and Jungle Creek Formations, the present assemblages are somewhat depauperate, and could well be separated from each other by cryptic faunal discontinuities.

ACKNOWLEDGEMENTS

Expenses for field-work were met by grants from the Department of Energy, Mines and Resources (DEMR D 13-4-37/73), and the National Research Council of Canada (NRC grant 4263) Ongoing help has been provided by Wayne Bamber, formerly of the Institute of Sedimentary and Petroleum Geology at Calgary, and now retained in that institution as Emeritus Scientist. Requests for assistance with literature have been aided by Guang R. Shi and Sangmin Lee, Deakin University (Burwood Campus), Melbourne.

Some photographs are processed by “local equalization”, which reduces the picture of overall shape and shade, but presents local detail and shows spine detail and micro-ornament very clearly.

BRACHIOPODS FROM THE HART RIVER FORMATION

Hartea venustus biozone

Content, lithology

The Hart River Formation is a sequence of recessive, light and dark brownish grey-weathering silty skeletal micritic and micritic limestone, silty calcareous dolomite and chert. Most of the rock in which the fossils are found is of dense and dark to almost black silt-grained rock, with shell preserved, but with fossil interiors often filled with secondary calcite, and other fossils were found in fine sandstone. Fossils come from the formation's type section, exposed along the north bank of the Peel River, as documented by Bamber in Bamber & Waterhouse (1971, pp. 225-226), and include collections from GSC 53740 to GSC 53746. Further occurrences of the fauna are documented in Waterhouse (1968c).

The formation rests on dark grey and reddish brown-weathering shale informally assigned to Unit 1 in Bamber & Waterhouse (1971), now referred to the Ford Lake Formation of Brabb (1969), assigned to a middle and late Visean age on the basis of spores examined by M. S. Barss, and by ammonoids identified by W. W. Nassichuk (Bamber & Waterhouse 1971, p. 45; Mamet & Bamber 1979, p. 49). No brachiopods have been found in Unit 1.

SYSTEMATIC DESCRIPTIONS

To a large degree, the classification follows that set out in the *Revised Brachiopod Treatise*, but aspects of this have become outdated, and parts follow observations and revisions in Waterhouse (2013, 2016, 2018), including proposed adjustments to the spelling for family group names, with the omission of extraneous lettering such as *id* and *at*, that have been devised to conform with medieval and later rules of Latin grammar. For family-group and ordinal-group names, it is preferred to graft the requisite ending directly on to the genus name, although this is admittedly a work still in progress.

Phylum Brachiopoda Duméril, 1806

Subphylum Linguliformea Williams et al., 1996

Class Lingulata Gorjansky & Popov, 1985

Order LINGULIDA Waagen, 1885

Superfamily **DISCINOIDEA** Gray, 1840

Family **DISCINIDAE** Gray, 1840

Genus ***Orbiculoidea*** d' Orbigny, 1847

Diagnosis: Strongly dorsibiconvex to convexo-planar, subcircular, ornamented by concentric growth rings, dorsal apex variably placed, ventral valve low with narrow pedicle track, closed anteriorly by a listrum, continued as internal tube to open in front of posterior margin.

Type species: *Orbicula forbesii* Davidson, 1848, p. 334 (1965 ICZN opinion 722) from Wenlock of England.

Orbiculoidea sp. A

Fig. 1, 2

1971 *Orbiculoidea* Bamber & Waterhouse, table 7, p. 116.

Material: A single ventral and dorsal valve each from GSC 53690 (but see p. 185) and GSC 53740, two ventral valves and three dorsal valves from GSC 53743 and two ventral valves and a dorsal valve from GSC 53749.

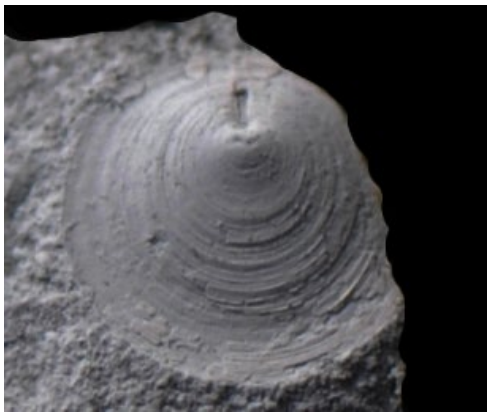


Fig. 1. *Orbiculoidea* sp. A, ventral valve GSC 140193 from GSC 53749, x8.

Description: The specimens are scattered as single valves, a ventral valve measuring 12mm wide, and very gently convex, and the dorsal valve more convex, with the apex in both valves subcentral, placed a little closer to the posterior margin. The pedicle track is narrow, indicated on some specimens by two slender and parallel ridges, and in other specimens by a low round-crested trough, which rarely may bear a median ridge. In some smaller specimens the rounded ridge reaches the posterior margin. Both valves are ornamented by closely spaced

concentric growth laminae, 0.5 to 1mm apart, with a number of intervening finer concentric growth laminae, 0.5 to 1mm apart, with a number of intervening and finer growth increments.

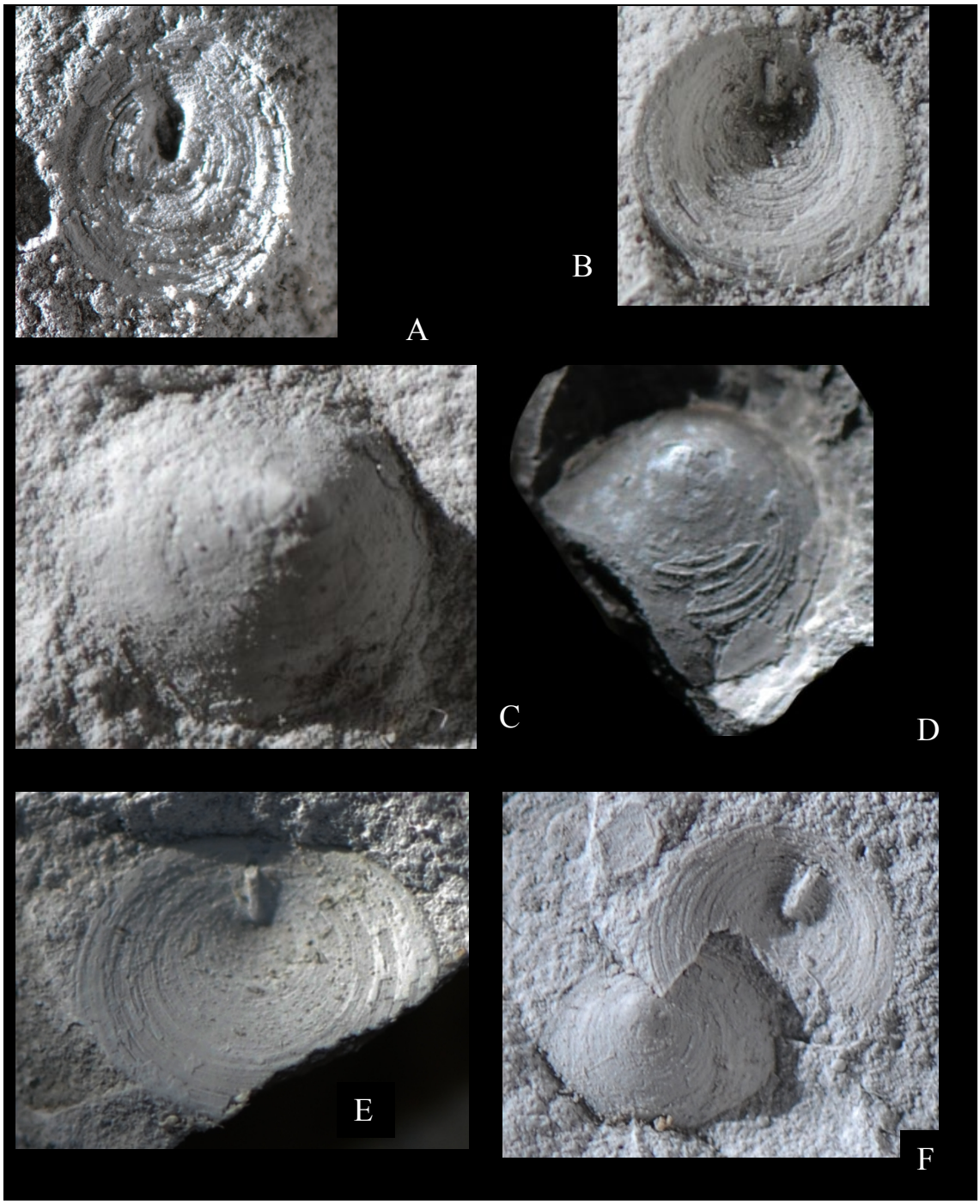


Fig. 2. *Orbiculoidea* sp. A. A, ventral valve GSC 140194 from GSC 53690, x4. (See p. 185) for location). B, ventral valve GSC 140195 from GSC 53749. C, dorsal valve GSC 140196 from GSC 53740. D, dorsal valve GSC 140197 from GSC 53743. E, ventral valve GSC 140198 from GSC 53749. F, ventral and dorsal valves GSC 140199 and 140200 from GSC 53743. Specimens in Fig. 2B - F x8.

Resemblances: This species was tabulated as *Orbiculoidea* from what is now called the lower *Quadralosia delicata* Zone in the Hart River Formation by Bamber & Waterhouse (1971). There are many similarities between the Hart River specimens and those of the Moorefield Formation in Arkansas, described by Girty (1911), and Girty recognized several varieties or subspecies, of which *Lingulidiscinia newberryi* var. *marshallensis* Girty (1911, p. 39, pl. 2, fig. 1-3) appears to be the closest, along with *newberryi ovata*. But no ventral valves were figured. Specimens from the Hart River Formation vary in their morphology much less than those recorded from the Moorefield Formation, and show a consistent position for the apex of each valve.

Subphylum Rhynchonelliformea Williams et al., 1996

Class Strophomenata Williams et al., 1996

Superorder PRODUCTIFORMI Waagen, 1883

Order PRODUCTIDA Waagen, 1883

Suborder PRODUCTIDINA Waagen, 1883

Superfamily **HORRIDONIOIDEA** Muir-Wood & Cooper, 1960

Family **HORRIDONIIDAE** Muir-Wood & Cooper, 1960

Subfamily **BAILLIENINAE** Waterhouse, 2013

Praehorridonia Ustritsky, 1962

Diagnosis: Small spines spaced in quincunx over ventral valve, none large; no row of dorsal spines, but dorsal spines numerous near start of trail. Ribs often prominent.

Type species: *Praehorridonia dorsoplicata* Ustritsky, 1962 from early Bashkirian of Taimyr Peninsula, OD.

Praehorridonia sp

Fig. 3

Material: A ventral valve from GSC 53690.

Description: The ventral valve is 60mm wide, 56mm long and 37mm high with large incurved umbo, wide hinge with cardinal extremities lost, and deep sulcus becoming narrow anteriorly over the trail. The shell is lirate with anterior undulations, and under slight wear displays very fine scattered moderately dense pustules. A few fine spines lie along the angular margin of

the hinge, and a few fine erect spines are visible on the lateral flanks, but much of the original spinose ornament has been obscured. Shell 8mm thick medianly.

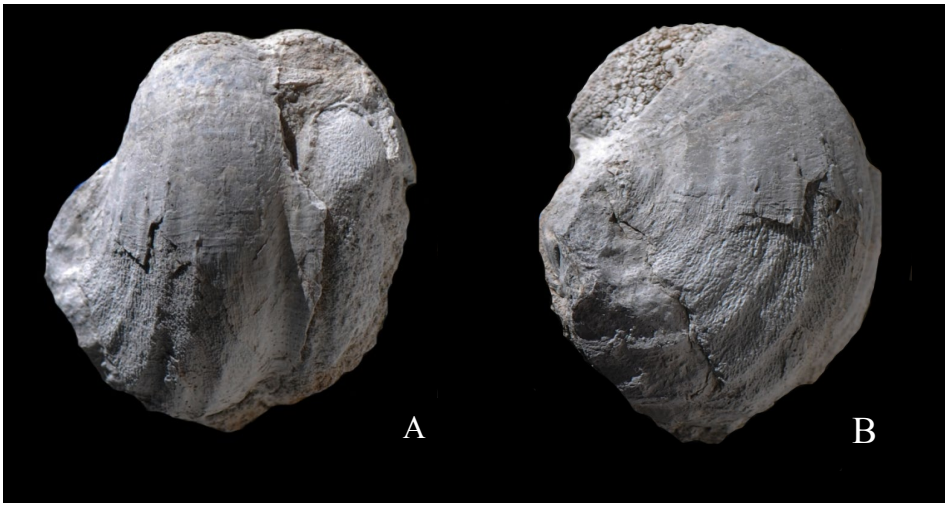


Fig. 3. *Praehorridonia* sp., A, B, ventral and lateral aspects of ventral valve GSC 140201 , x1, from GSC 53690. (See p. 185).

Resemblances: With no dorsal valve, and with hinge spines and ventral interior obscure, it is difficult to determine the generic affinities of this specimen, but the size, shape and thick shell are strongly suggestive of horridonioid stock, which is seldom found in beds as old as upper Visean or Serpukhovian. The one exception according to Brunton et al. (2000) is *Praehorridonia* Ustritsky, 1962, extensively figured in Ustritsky & Chernyak (1963) from the Siberian Arctic, and the Canadian specimen matches this genus in size, shape and rugation, though more needs to be known about hinge spines especially. The Canadian specimen is close to but less like *Bailliena* Nelson & Johnson, 1968, a genus which has much stronger ventral spine bases, and found in slightly younger beds of the Ettrain Formation s. l. Both genera were grouped as members of Baillieninae by Waterhouse, 201, characterized by the absence of dorsal hinge spines and other features.

Superfamily PRODUCTOIDEA Gray, 1840

Family **RETARIIDAE** Muir-Wood & Cooper, 1960

Subfamily **RETARIINAE** Muir-Wood & Cooper, 1960

Tribe **RETARIINI** Muir-Wood & Cooper, 1960

Genus ***Kutorginella*** Ivanova, 1951

Diagnosis: Ventral spines subuniform in strength, including one or more well-formed rows below the umbonal slopes, dorsal spines erect, may be numerous. Trail may be nasute. No ridge close to the inner ventral ears, nor groove along inner margin of dorsal ears.

Type species: *Kutorginella mosquensis* Ivanova, 1951 from Kasimovian-Gzhelian of Moscow Basin, OD.

Discussion: The species from the Hart River beds occurs in rocks somewhat older than the Kasimovian to Lower Permian age assigned to *Kutorginella* in Brunton et al. (2000, p. 472). But there have been a number of reports of the genus in Moscovian faunas and a little older, and the morphology of the present form reveals only limited distinction from typical *Kutorginella*. Several dorsal valves confirm that there is no groove between dorsal disc and ears, unlike the arrangement in Tribe Rigrantiini Lazarev, and a number of ventral valves show that there was no distinct ridge underlying the row of strong spines that curve from the ventral umbo along the outer disc close to each ear, unlike the arrangement in Subtribe Antiquatoninai Waterhouse. Unfortunately the ventral hinge row of spines is not well shown in present material, and only indicated by the presence of opposing spine pits on the dorsal valve. But there is more than one row of major spines along the outer umbonal slopes, which is unusual for *Kutorginella* and implies a different genus. *Tesuquea* Sutherland & Harlow (1973) of Morrowan age in New Mexico has two rows of strong spines along the outer umbonal slopes, compared with three in the present form, and finer overall ornament.

"Kutorginella" primigenius n. sp.

Fig. 4 - 7

Derivation: primigenial – primal, aboriginal, Lat.

Material: Seven ventral valves and three dorsal valves from GSC 53740, one ventral valve from GSC 53960. For query over GSC 53960, see p. 185.

Diagnosis: Well developed ribs and spines, two or three lower umbonal slope rows anteriorly.

Holotype: Specimen GSC 140205 figured in Fig. 5, 6, here designated.

Description: The specimens are deformed, the ventral valves as a rule squashed lengthwise, and individuals are estimated to have been originally about 50mm wide, over 40mm long, and at least 25mm high, without counting the ears, which are often lost. The ventral umbo is

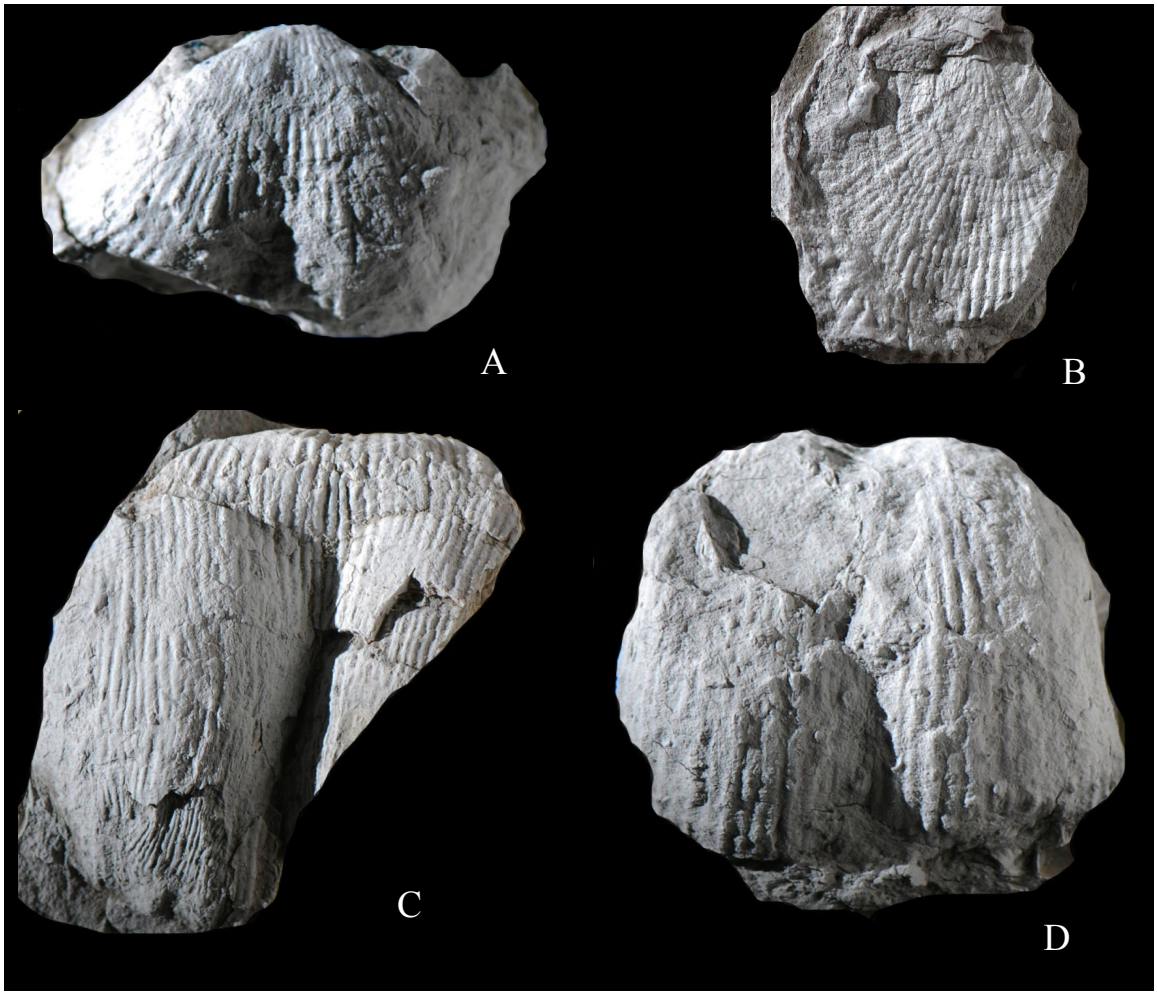


Fig. 4. "*Kutorginella" primigenius* n. sp. A, D, posterior and anterior ventral valve GSC 140202 from GSC 53740. B, dorsal external mould GSC 140203 from GSC 53740. C, trail of ventral valve GSC 140204 from GSC 53470. Specimens x2.

broad with an angle of 100°, and incurved, with high posterior walls, the visceral disc arched, and trail longer than the disc. No clearly defined umbonal slope ridge is preserved, and rare suggestions of short partial ridging seem to have been caused by quirks of deformation. A sulcus commences some 10mm in front of the umbonal tip and widens and deepens to the anterior margin in some specimens, and shallows in others towards the anterior margin. The

dorsal valve is gently concave, with small protruding beak and wide hinge, that bears small alate ears. Although obscure, maximum width is likely to have been near mid-length. The dorsal trail is long and geniculate. The ears are not separated from the disc by a groove, unlike the arrangement in Rigrantiini Lazarev. Ribbing is strong on both valves, three to four in 5mm over the ventral trail, with most ribs persistent in most specimens, though increasing by intercalation in some specimens, and splitting in front of spines. Ribs are slightly finer over the dorsal disc, opposed to the ventral interspaces, and whilst some increase by intercalation, others increase by branching. Low commarginal rugae lie especially over the ventral disc, imparting a reticulate pattern, and become stronger laterally, whereas they are largely absent from the trail. Ventral spines follow the pattern normal for members of Retariidae Muir-Wood & Cooper, 1960. Over the disc, they are broad and suberect, with elongate bases broader than the ribs, and lead forward from one rib, to be followed in front of the spine by two up to three finer ribs. Over the trail, spines are finer and erect, arising from the crest of single ribs with little disturbance, and are numerous. Poor preservation masks the presence of a ventral hinge row of spines, but such are indicated on the dorsal valve by a row of strong dimples close to the hinge. A row of sturdy erect erect spines extends from close to the ventral umbo along the base of the umbonal slopes, and the adjoining two or even three rows are also strong (Fig. 6). As stated previously, the row does not lie along a ridge. Spines are more limited over the dorsal valve, fine and erect, lying in commarginal rows over parts of the disc and a number of sturdy spine bases emerge from the inner ears, with a few close to the hinge. Elongate pits lie over the disc in a quincunxial pattern. There is no nasutation.

Little of the interior is visible, apart from a small ventral adductor platform, and the broad but low base of the cardinal process. A high marginal ridge lies around the dorsal disc. Resemblances: *Kutorginella mosquensis* Ivanova is readily distinguished by its nasute trail. Another species with nasute trail, *K. orientalis* (Fredericks, 1915, pl. 2, fig. 5, 8, pl. 3, fig. 6, 8, 10, 11) is close in many aspects, but is smaller and has a more geniculate trail. It is of Sakmarian age in the southern Urals. From Late Carboniferous and early Permian faunas of the Yukon Territory, *K. yukonensis* Sarytcheva & Waterhouse (1972, pl. 7, fig. 1, 2; Shi & Waterhouse 1996, pl. 7, fig. 1-19; Waterhouse 2018, Fig. 44-50 and see also *K. triangulata* Sarytcheva & Waterhouse, 1972, pl. 7, fig. 3-8) has slightly finer ribs, and flatter, longer

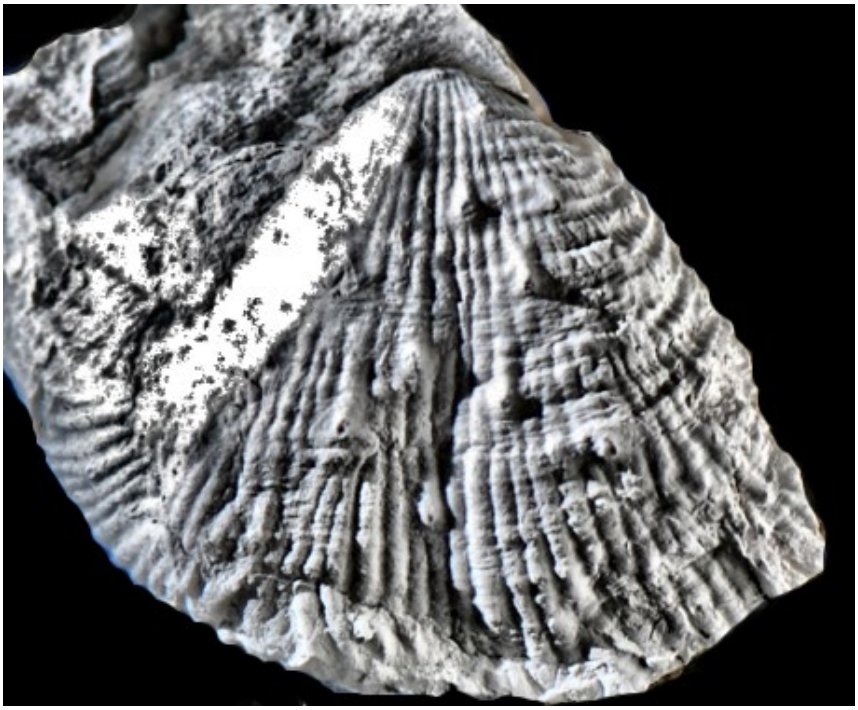


Fig. 5. *Kutorginella primigenius* n. sp., venter of the ventral valve holotype GSC 140205 from GSC 53740, x6, processed by local equalization.

Fig. 6. *Kutorginella primigenius* n. sp. A, lateral view of ventral valve holotype GSC 140205 from GSC 53740, x3. Arrows point to the row of prominent spines developed at the base of the umbonal slopes next to the inner ear, and show that no antiquatoniin ridge was developed, and that further major spines formed several rows along the outer umbonal slopes.

dorsal disc and less extended trail. *K. neoinflatus* (Licharew, 1939, pl. 21, fig. 2) from the Upper Carboniferous of the Donets Basin and Russian Platform, and also reported from the

Lower Permian of the Petchora Basin by Mironova (1964), is distinguished from the present form by its stronger commarginal rugae.

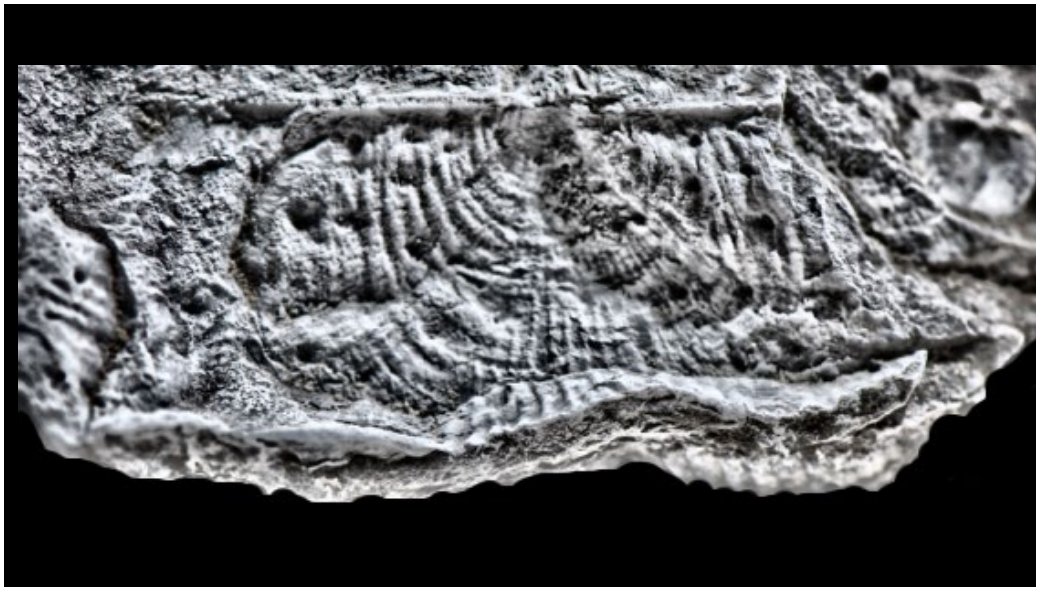


Fig. 7. *Kutorginella primigenius* n. sp., dorsal valve GSC 140206 under local equalization, x4. Note the narrowness of dorsal ribs in this specimen.

Family **BUXTONIIDAE** Muir-Wood & Cooper, 1960

Subfamily **BUXTONIINAE** Muir-Wood & Cooper, 1960

Tribe **BUXTONIINI** Muir-Wood & Cooper, 1960

Genus ***Flexaria*** Muir-Wood & Cooper, 1960

Diagnosis: Valves ornament by erect crowded spines with elongate bases, many arising from very fine fila.

Type species: *Productus arkansus* Girty, 1910a, p. 216 from Chester-Fayetteville Shale and Batesville Sandstone (upper Visean, lower Serpukhovian) of Oklahoma, OD.

Flexaria echinata n. sp.

Fig. 8 - 12

1971 *Flexaria* sp. Bamber & Waterhouse, p. 114, pl. 1, fig. 5, 6, 19.
1971 ?*Flexaria* sp. Bamber & Waterhouse, p. 114, pl. 1, fig. 17.

Fig. 8. *Flexaria echinata* n. sp., ventral aspect of holotype GSC 140207 with valves conjoined, from GSC 53740, x3, processed by local equalization.

Fig. 9. *Flexaria echinata* n. sp., dorsal aspect of holotype GSC 140207 with valves conjoined, from GSC 53740, x3, processed by local equalization.

Derivation: echinus – sea-urchin, Lat.

Diagnosis: Little inflated medium-sized shells, with posterior micro-ornament dominated by small erect spines, replaced anterorly by spinose fila.

Holotype: Specimen GSC 140207 illustrated in Fig. 8, 9, here designated.

Material: Seven ventral valves, three dorsal valves and three specimens with valves conjoined, from GSC 53740.

Description: The specimens are composed mostly of incomplete ventral valves and more complete dorsal valves, with ornament well preserved. Specimens are only slightly distorted. The largest ventral valve is 52mm wide but only 8mm high, and a specimen with valves conjoined is 36mm wide, 30mm long and 6mm high, but the trail is not preserved. A small ventral valve is 22mm wide, 17mm long and 5mm high. A dorsal valve is 37mm wide and 28mm long. The ventral valve is gently convex, with inconspicuous if any ears, a very shallow sulcus over the anterior disc, and maximum width placed behind mid-length. The ventral umbo with an angle of 85^{o} to 90^{o} protrudes only slightly beyond the hinge, which has a very low ginglymus. The umbonal walls are low, and cardinal extremities highly obtuse. The ventral trail curves evenly on from the disc, but the shallow sulcus disappears anteriorly, probably where the trail commences. The dorsal valve is gently concave, with median reduction in curvature and anterior very gentle median swelling, and posterior lateral ears are weakly indicated by a change in slope. The trail is short, and only slightly inclined from the disc. The ventral ornament is dominated by short raised spine bases, three in 1mm posteriorly, strengthening to about two in 1mm anteriorly, and one and a half to two in 1mm anteriorly in the largest specimen. Over the anterior shell, these spine bases may lie along the crests of fine ribs of similar spacing. The ribs are strengthened at intervals by the spine bases, and increase by branching. Up to ten growth increments are present in 1mm over the ventral valve. For the first 7mm of shell width, the spines arise directly from the shell, without elongate bases and without ribs, and growth increments are also prominent. Over much of the posterior shell, the spine bases also appear discrete, and the connecting riblets cannot be discerned, or are very low and fine, this varying in different specimens and over different parts of the shell. Complicating the ornament is the presence of fine close-set commarginal rugae or growth ridges, numbering four in 5mm posteriorly, spaced further apart and lower in

front. The spine bases in some instances lie over the posterior tread of these rugae, but in other instances often continue across the rugae, and overall appear to have no regular relationship to the rugae. In the dorsal valve the ornament is much the same, and the strength of the spine bases more noticeably variable, and the commarginal rugae narrower, and intervening growth increments are visible, up to five between a pair of rugae. The spines are fine and erect, projecting from the anterior end of each spine base. A large dorsal valve 46mm wide, 30mm long and 5mm high has closely spaced commarginal growth rises and packed spine bases of similar nature, but the spine bases lack connecting ribs.

Little of the interior is visible. There are signs that the dorsal median septum was slender and extended for slightly more than the posterior third of the shell length, and the base of the cardinal process is visible externally.

Resemblances: In the type species, *Productus arkansanus* Girty (1910a), fine ribs with spines commence over the umbones, whereas the umbonal region in the present species tends to be spinose with ribs on only some specimens. Spines of the present species have much shorter bases and are more numerous than in the type species, which does show only erect spines over the ears of both valves as in the present form. Easton (1942, 1943) reported *Buxtonia arkansana* (Girty) from the Pitkin Limestone, which he deemed to be of Chesterian age. A sketch purporting to be the same species was offered in Massa et al. (1974, text-fig. 3.3; pl. 7, fig. 1) from the upper Visean of Tunisia, but radial costae are coarser. *P. arkansanus multiliratus* Girty (1910a, 1911) is similar. Specimens figured as *Flexaria arkansus* by Pavlova et al. (1983, pl. 13, fig. 12-15) from Early Carboniferous of southern Mongolia have more prominent ventral spine bases, and possible dorsal buttress plates, and so seem unlikely to be congeneric.

Buxtonia semicircularis Sutton & Wagner (1931, pl. 5, fig. 20-22), also figured in Sutton (1938, pl. 65, fig. 1), from the Kinkaid Limestone of Kentucky, has long spine bases and a broad well defined sulcus. *Productus galeanus* Girty, 1927 from the Madison limestone of Idaho, assigned to *Flexaria* by Muir-Wood & Cooper, 1960, p. 259, has much stronger ribs.

Productus (*Pustula*) *piscariae* Waterlot (1932, pl. 3, fig. 3-11) from beds of Westphalian age in Belgium appears to be related. The spine bases are long and prominent, and the ribs subdued.

Fig. 10. *Flexaria echinata* n. sp., dorsal valve GSC 140208 , with fragment of external ventral valve to left, from GSC 53740, x3.

Fig. 11. *Flexaria echinata* n. sp., dorsal valve GSC 140209, with part of ventral umbo, from GSC 53740, x3, processed by local equalization.

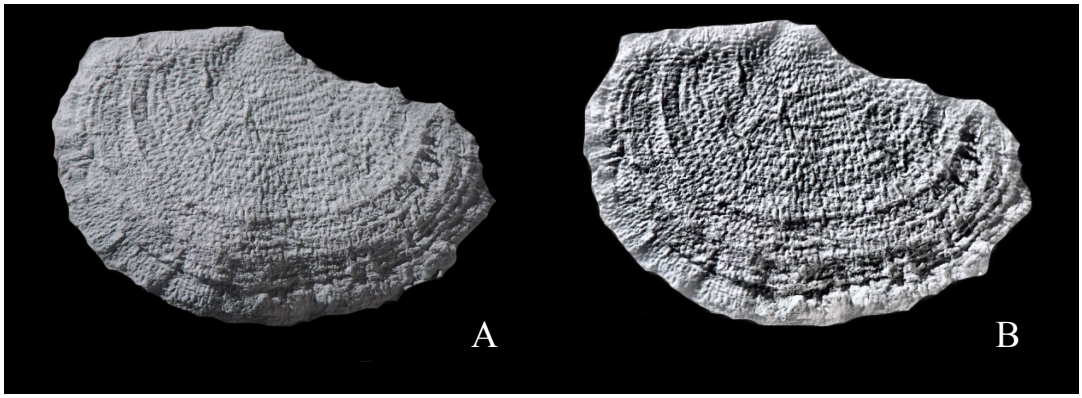


Fig. 12. *Flexaria echinata* n. sp., dorsal valve from internal aspect, GSC 140210 under ordinary light and reproduced also by local equalization, from GSC 53740, x1.5.

The species originally described as *Productus scabriculus* (not Sowerby) by Diener (1903, p. 141, pl. 7, fig. 15-17) and renamed *P. scabriculus spitiensis* by Diener (1903, p. 143) was referred with caution to *Flexaria* by Waterhouse & Gupta (1977, p. 156, pl. 1, fig. 6, pl. 2, fig. 6-16) and Waterhouse & Gupta (1979, p. 125, pl. 9, fig. 5-9, pl. 10, fig. 1, 2), with further references provided, though ignored by Brunton et al. (2000, p. 499). It is found in the Fenestella Shales of Kashmir, judged to be of upper Visean or lower Serphukovian age. The Canadian species is moderately close in shape, but has slightly more prominent but narrower and just as numerous ventral spine bases. Sarkar (1965) regarded *Flexaria spitiensis* as a precursor for *Productus lidarensis* Diener (1915, pl. 2, fig. 4a, b), also from Kashmir. This has a more massive and incurved umbo, though similar in ornament. Only a ventral valve is known, so that the full range of morphological variation of *lidarensis* is poorly known.

Superfamily **ECHINOCONCHOIDEA** Stehli, 1954

Family **ECHINOCONCHIDAE** Stehli, 1954

Subfamily **ECHINOCONCHINAE** Stehli, 1954

Tribe **ECHINOCONCHINI** Stehli, 1954

Genus ***Calliprotonia*** Muir-Wood & Cooper, 1960

Diagnosis: Small to median in size, spines of two sizes each in several rows over commarginal bands on each valve, tend to be uniform posteriorly and anteriorly on each

commargon, marginal ridge high.

Type species: *Calliprotonia renfrarum* Muir-Wood & Cooper, 1960, p. 247 from the Finis Shale (Upper Pennsylvanian), Texas, United States, OD.

Discussion: The genus ranged from Lower Carboniferous (upper Visean) to Lower Permian (Artinskian), with Upper Devonian (Famennian) forebears.

Calliprotonia sp.

Fig. 13

Material: A ventral valve from GSC 53742.

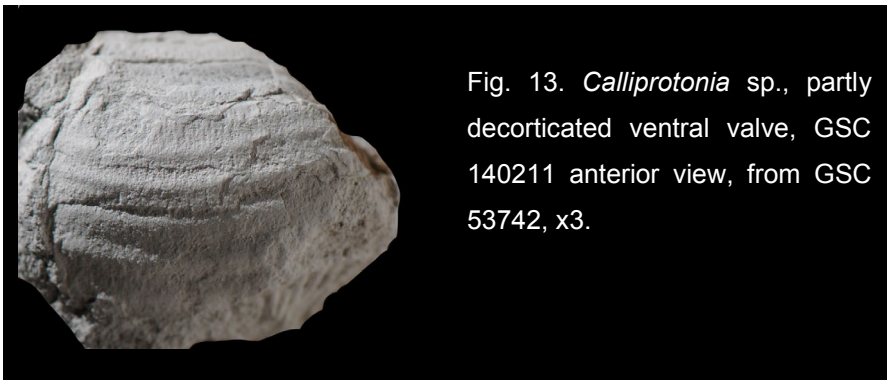


Fig. 13. *Calliprotonia* sp., partly decorticated ventral valve, GSC 140211 anterior view, from GSC 53742, x3.

Family **SENTOSIIDAE** McKellar, 1970

Subfamily **TUBERSULCULINAE** Waterhouse, 1971

Tribe **TUBERSULCULINI** Waterhouse, 1971

Discussion: Krotovini Brunton et al. (1995) is a junior synonym, *Krotovia* being close to and ancestral to *Tubersulculus*, as discussed in Waterhouse (2013) and Waterhouse (2018, p. 143).

Genus ***Krotovia*** Fredericks, 1927 (1928)

Diagnosis: Small thin-disced species, numerous spines arranged in quincunx, with slightly swollen not elongate bases, intervening dimples prominent on dorsal valve, weakly developed marginal ridges and quadrifid cardinal process.

Type species: *Productus spinulosus* Sowerby, 1814, p. 155 from Lower Carboniferous (Asbian) of Fermanagh, Ireland, OD.

Krotovia sp.

Fig. 14, 15

Material: Two incomplete ventral valves from GSC 53742, and dorsal valve from GSC 53740.

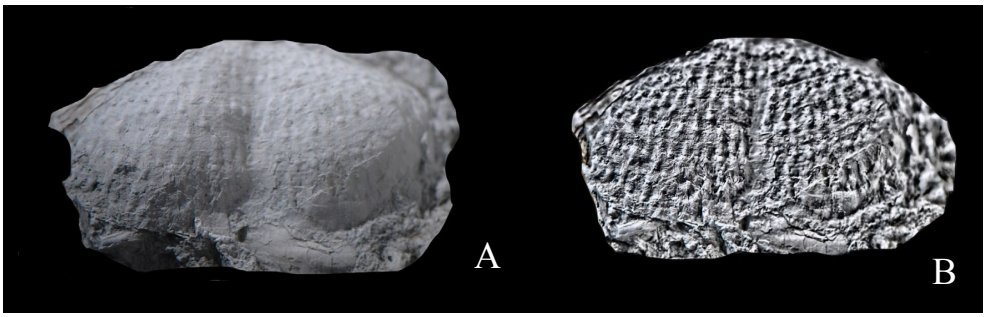
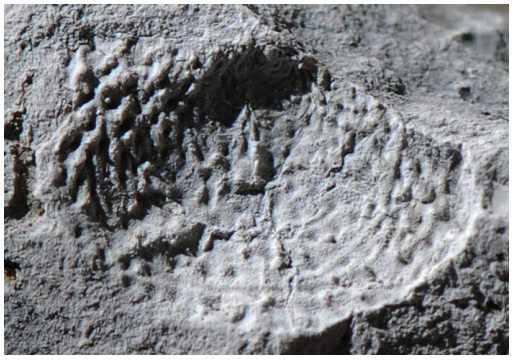


Fig. 14. *Krotovia* sp. A, B, ventral valve GSC 140212 from GSC 53742, x2, reproduced under ordinary light and by local equalization.

Description: The ventral valve is crushed and now measures 23mm wide, 15mm long and 7mm high. It has a moderately developed anterior sulcus, and fine erect closely spaced spines only slightly if at all elongate or swollen bases, six in 5mm anteriorly. The dorsal valve, only 13mm wide, shows only a very low median rise anteriorly, and its surface is diversified by pustules, pits and erect spines.

Fig. 15. *Krotovia* sp., dorsal valve GSC 140213 from GSC 53740, x5.



Resemblances: The fine spines are especially typical of *Krotovia* Fredericks, and the anterior sulcus is less developed than in *Tubersulculus* Waterhouse, 1971, but perhaps anticipated the inception of that genus from within the ranks of *Krotovia*, which commenced in older Carboniferous faunas, and lacked the well-formed sulcus and tubiform trail of *Tubersulculus*.

Suborder STROPHALOSIIDINA Waterhouse, 1975

Superfamily **STROPHALOSIOIDEA** Schuchert, 1913

Family **DASYALOSIIDAE** Brunton, 1966

Subfamily **QUADRATIINAE** Lazarev, 1989

Diagnosis: Ventral body spines at low angle, row of weak spines near hinge, dorsal spines variable, numerous, rare or absent, subdued regular commarginal rugae on both valves; marginal ridges may be present.

Discussion: This subfamily, now containing the genera *Quadratia* Muir-Wood & Cooper, *Cyphotalosia* Carter, *Dichacaena* Cooper & Dutro and *Quadralosia* Waterhouse, was classed in Araksalosiidae by Lazarev (1989) and Brunton et al. (2000, p. 582), but members lack the lateral buttress plates and usually elongate ventral spine bases which characterize that family. The ventral valve in Quadratiinae carries numerous fine ventral spines, including a row close to the ventral hinge, rare dorsal spines, and subdued commarginal laminae and very low rugae on both valves, and overall looks externally very like members of Echinalosiinae Waterhouse, 2001, apart from the fine rugae and, as a rule, uniformly fine spines. The overall morphology of the subfamily suggests that its position should be reassessed from that arranged in Brunton et al. (2000), and moved from Araksalosiidae Lazarev to Dasyalosiidae Brunton.

Quadratia is widespread and well preserved, and fails to show any umbonal cicatrix, and although Brunton et al. (2000, p. 582) stated that a pseudodeltidium was absent, one was observed in type *Quadratia* by Campbell (1966). One was also figured for *Q. egregia* by Carter (1967), and one is here figured for a related genus from Canada (Fig. 20). *Quadratia* is distinguished principally by its wide hinge, low interareas, fine spines, and low crowded commarginals, less conspicuous than in Rhytialosiinae, but nonetheless present, even though they are somewhat masked by commarginal laminae on the ventral valve of the type species, *Quadratia hirsutiformis*. This species has a heavy internal ventral posterior ridge, not seen in all of the associated genera as far as is known, but also not well displayed by other species of *Quadratia*. A dorsal pit lies in front of the broad sub-bifid cardinal process.

Dichacaena Cooper & Dutro, 1982 of Givetian (Middle Devonian) age has weak commarginal growth laminae and rugae, and fine recumbent ventral spines, but no

conspicuous hinge row of spines and no dorsal spines. As stressed by Cooper & Dutro (1982), the bifid cardinal process (which is well known for the associated rather than type species) is like that of *Eostrophalosia* Stainbrook, 1943, and also *Caucasiproductus* and *Strophoproductus*, genera which have numerous dorsal spines. The figure in Cooper & Dutro (1982, pl. 12, fig. 54) suggests dorsal spine bases, though this is presumably incorrect, according to the proferred diagnosis of the genus. *Quadratia egregia* Carter, 1967, p. 284 also lacks dorsal spines, to suggest possible generic distinction, with its tribal and subfamily affiliations therefore open to further study.

Genus ***Quadralosia*** Waterhouse, 2013

Diagnosis: Transverse shells with wide but low interareas, subdued wrinkles, fine spines of two distinct diameters over ventral valve, including erect row along hinge, dorsal spines fewer and erect.

Type species: *Quadralosia delicata* Waterhouse, 2013, from Hart River Formation (Late Mississippian – Chesterian) of Yukon Territory, Canada, OD.

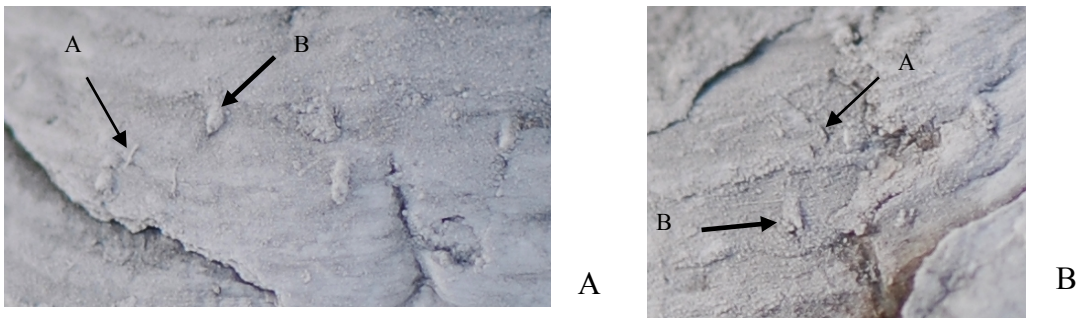


Fig. 16. *Quadralosia delicata* Waterhouse, detail of ornament on ventral valve, holotype GSC 133257, x8, from GSC loc. 53743. Arrows point to slender (A) and thicker (B) spines.

Discussion: The Canadian species from the Yukon Territory shows some differences from *Quadratia* Muir-Wood & Cooper, 1960, in so far as the semiprostrate spines of one size over the ventral valve, shared with *Quadratia,* are accompanied in the Yukon material now assigned to *Quadralosia* by additional much finer erect and prostrate spines. The more prominent spines are 0.2 to 0.3mm in diameter, and appear to be ordered over most of the

valve in commarginal rows, although in detail they are not regularly arranged, protruding from different growth lines and rugae, and somewhat more disordered over the trail. In addition, there are much more slender and more prostrate spines less than 0.1mm in diameter, disordered in distribution, usually over the anterior half of the valve, and prostrate over the median valve, and tending to be more erect near the shell margins. Over parts of the shell the finer of the two sets of spines may be bunched as two to four in a cluster. According to available descriptions, as confirmed by figures, *Quadratia* is typified by spines of subuniform diameter, and no specimens show any signs of spines equivalent to the finer set.

Quadralosia delicata Waterhouse, 2013

Fig. 16 - 25

1961a *Productella hirsutiformis* (not Walcott) – Nelson, pl. 1, fig. 2.
1971 *Quadratia* cf. *hirsuteformis* [sic = *hirsutiformis*] (not Walcott) – Bamber & Waterhouse, p. 110, pl. 1, fig. 1-4.
2013 *Quadralosia delicata* Waterhouse, p. 235, Fig. 7.28 - Fig. 7.32.

Diagnosis: Shells with thin body corpus, slightly upturned ventral ears, ventral umbo may show small cicatrix, ventral interarea low with pseudodeltidium, posterior lateral ridges not high. Well defined row of ventral hinge spines, major ventral spines thin and loosely arranged in commarginal rows, additional much more slender spines, prostrate over shell and becoming erect over trail, irregular in distribution. Dorsal spines concentrated on ears.

Holotype: GSC 133257 from GSC loc. 53743, Hart River Formation, Yukon Territory, Canada, figured in Waterhouse (2013, Fig. 7.28C and Fig. 7.32C) and herein as Fig. 16, 17 and Fig. 20C, OD.

Dimensions in mm:

Specimen GSC	Width	Length	Height	
133257	34	24	9.5	holotype
133252	24	15.5	4.5	
133251	29	19	11.5	distorted
133260	32	28	10	
133262	32	22	?5	
133274	27	19	5	

Material: Five ventral valves and a specimen with valves conjoined from GSC 53740, one ventral valve and a specimen with valves conjoined from GSC 53742, six ventral valves, ten dorsal valves and twenty specimens with valves conjoined with additional material from GSC 53743, four ventral valves, eight dorsal valves and eleven specimens with valves conjoined

from GSC 53745, one ventral valve from GSC 53746, four ventral valves and two dorsal valves from GSC 53748, and two ventral valves and five dorsal valves from GSC 53749.

Fig. 17. *Quadralosia delicata* Waterhouse, detail of ornament on ventral valve, holotype GSC 133257, x8, from GSC loc. 53743. Slender arrow points to a slender prostrate spine, and thicker arrow to a thick suberect spine. Figure processed by local equalization.

Description: Shells of moderate size, up to 35mm wide and 28mm long, with thin visceral disc and trail curving smoothly forward. Maximum width lies toward the anterior quarter of the shell length, and the hinge is almost as wide, with an extremely low ventral interarea bearing a narrow arched pseudodeltidium that may be lost in later ontogeny, and low dorsal interarea, standing at high angle to disc, bearing low horizontal markings and broad chilidium marked by outward sloping ridges. A very small smoothly convex nepionic part lies in front of the notothyrium on the dorsal valve. The cardinal extremities are acute and the ventral ears are

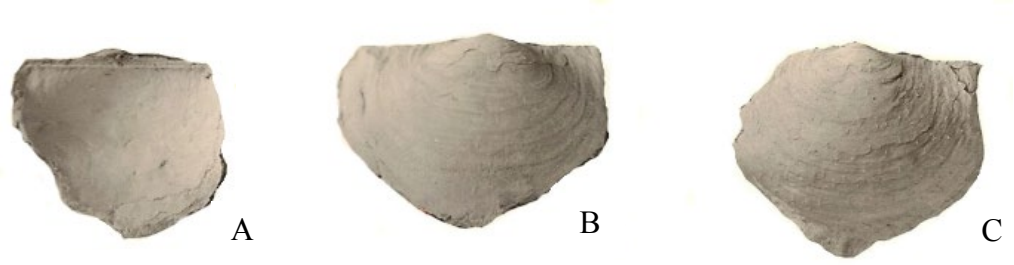


Fig. 18. *Quadralosia delicata* Waterhouse. A, ventral valve GSC 26438 from GSC 53745. B, ventral valve GSC 26439 from GSC loc. 53743. C, ventral view of GSC 26440 from GSC 53743. Specimens x 1.

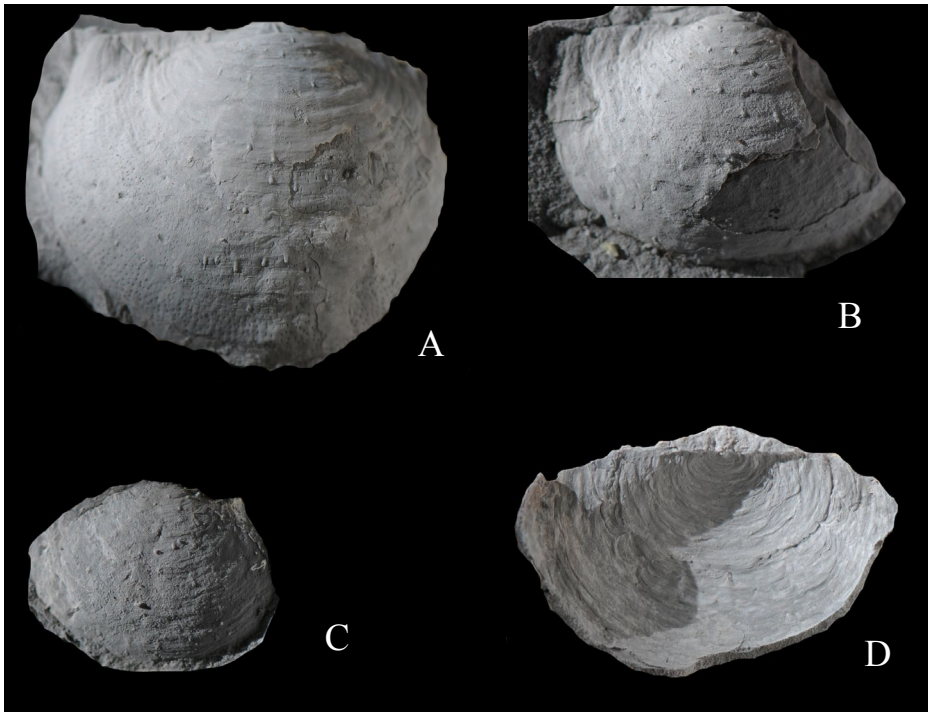


Fig. 19. *Quadralosia delicata* Waterhouse. A, ventral valve GSC 140214 from GSC 53743. B, ventral valve GSC 140215 from GSC 53743. C, ventral valve GSC 140216 from GSC 53743. D, dorsal aspect of specimen with valves conjoined, GSC 140217 from GSC 53744. Specimens x2.

slightly upturned. There is no sulcus or fold, and umbonal slopes are low and short. Ventral spines cover the valve, small and erect without prolonged or swollen bases. The spines at the hinge seem to form part of a row that follows a growth line or rugation, and the spines are no thicker than elsewhere in less mature specimens, but become broader with maturity, reaching a diameter of 0.65mm (Fig. 24). They project posteriorly and are erect, whereas those over the disc and trail are semi-prostrate and project forwards, and may cause short grooves and folds in the exterior, where external shell may partly enwrap an overlying prostrate spine. The thicker spines are about 2 to 2.5mm apart with 2-3mm between rows anteriorly, usually 0.2 to 0.3mm in diameter, rarely 0.4mm, and the thinner spines more irregularly dispersed, 0.1mm in diameter or slightly less, with further detail provided in the generic description and in figures. Dorsal spines are like those of the thicker ventral spines and are suberect with a number over the ears. Both valves are covered by very low and regular commarginal growth increments, some ten in 1mm, superimposed over low irregular rugae and lamellae.

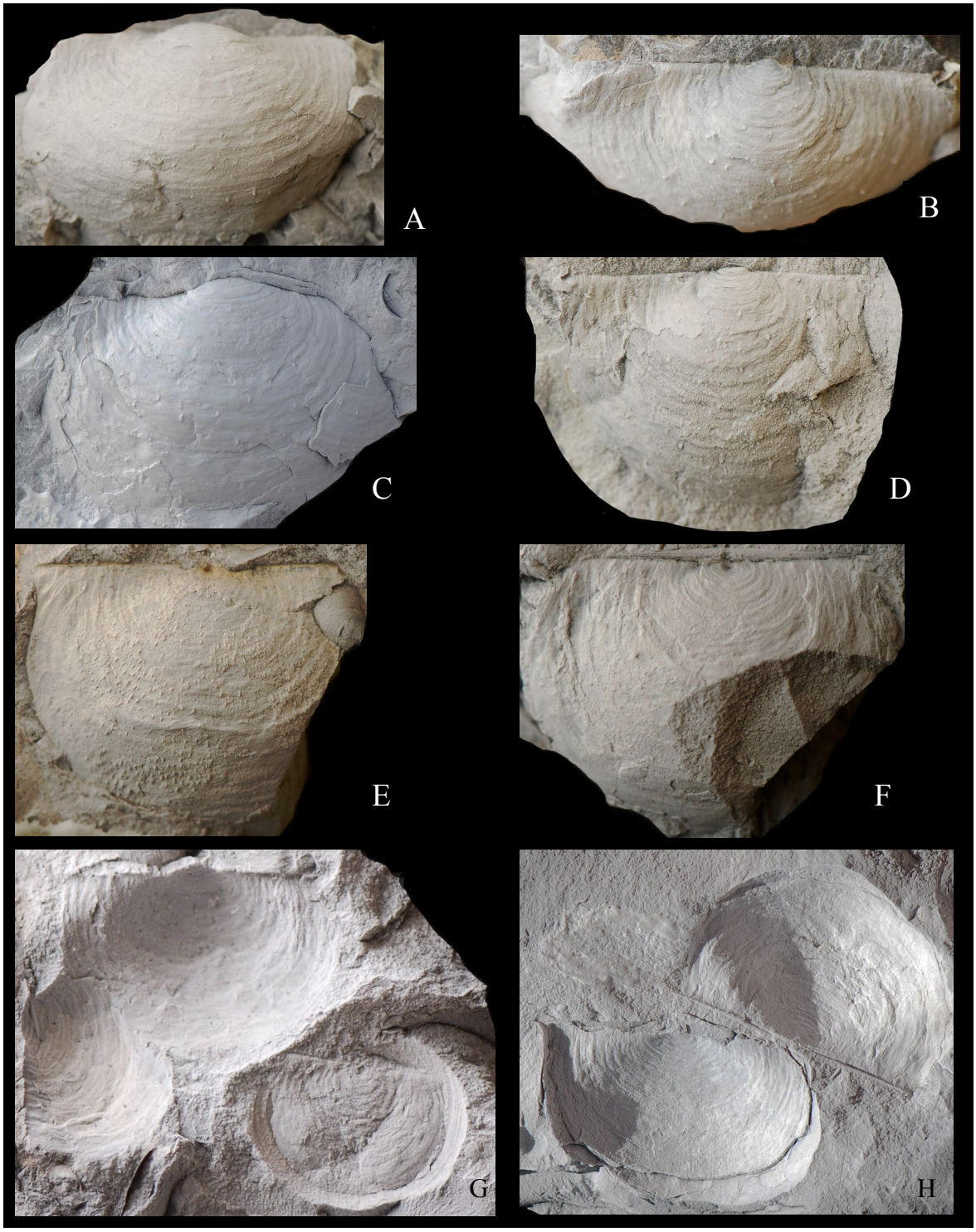


Fig. 20. *Quadralosia delicata* Waterhouse. A, B, ventral and posterior ventral aspects of GSC 133254 from GSC loc. 53745, x1.8. C, holotype, ventral valve GSC 133257, from GSC loc. 53743, x1.7. D, ventral valve GSC 133252 from GSC loc. 53743, x3. E, decorticated dorsal valve (ventral aspect) BR 133255 from GSC loc. 53749, x2. F, decorticated external mould of a dorsal valve GSC 133263 from GSC loc. 53745, x3. G, dorsal aspects of ventral valves and dorsal views of two specimens with valves conjoined, GSC 133256 and GSC 133257 from GSC loc. 53743, x2. H, dorsal views of two specimens with valves conjoined, GSC 133561 and 133262, from GSC loc. 53743, x1.6.

Internally, ventral adductor scars are ovally subquadrate and smooth. Diductor impressions are too faint to be visble. The dorsal septum commences within the adductor field, and does not extend as far as mid-length. Anterior adductors are smooth and slightly raised, and brachial shield ridges are low and enclose large areas. A low anterior ridge lies around the anterior disc. The floor of the valve bears well spaced small elongate pustules, that persist onto the trail. There is no prominent hinge ridge across the ears.

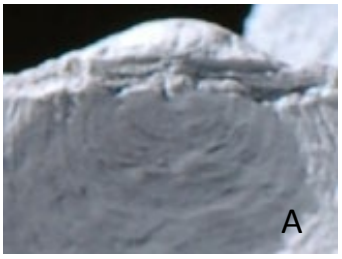
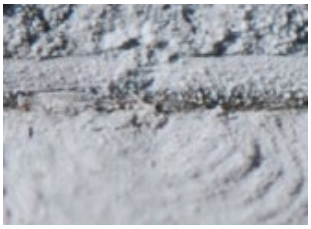


Fig. 21. *Quadralosia delicata* Waterhouse, posterior detail of showing pseudodeltidium. A, GSC 133260. B, external mould – see Fig. 22, GSC 140218. From GSC loc. 53743, x4,



Resemblances: This species is very close in most known detail to *Quadratia hirsutiformis* (Walcott 1884, p. 133) from lower Chesterian of Oklahoma, United States, as revised by Muir-Wood & Cooper (1960). External differences are that the cardinal extremities are more pointed in the Canadian species, and the spines more closely spaced, with about five in 10mm in the Canadian form, compared with three in 10mm in Walcott's species, and dorsal

Fig. 22. *Quadralosia delicata* Waterhouse, dorsal valve external moulds GSC 140218 and 140219 with ventral interarea from GSC 53743. Specimens x2.

10mm in the Canadian form, compared with three in 10mm in Walcott's species, and dorsal spines may be more common. The critical difference lies in the nature of the ventral spines, those of *Quadratia* being of uniform diameter, as far as described, those of the new genus being of two differing diameters, with a finer set of slender spines being largely prostrate. Muir-Wood & Cooper (1960, p. 161) stated that a pseudodeltidium was absent from *hirsutiformis*, whereas it is definitely present in the Canadian form. However Campbell (1966) challenged the observation for *hirsutiformis*, asserting that one was present in at least some specimens. No chilidium was reported for *hirsutiformis*, but this may reflect a change in specimens with increased maturity, the chilidium being displaced by the cardinal process. Commarginal rugae are low and fine in the Canadian form. Walcott's species has larger ventral adductor scars, and a heavy posterior ridge that continues across the ears, whereas no comparable ridge is seen in the Canadian form. Muir-Wood & Cooper (1960) illustrated much more emphasized muscle impressions, probably a reflection of greater maturity than is found in the Canadian specimens.

Fig. 23. *Quadralosia delicata* Waterhouse. GSC 133274, from GSC loc. 53749, showing detail of ornament, x10, with slender arrow pointing to a fine spine, and thicker arrow pointing to a more sturdy spine.

Productus hirsutiformis batesvillensis Girty (1911, p. 51, pl. 3, fig. 5) from the Moorefield Shale or northern Arkansas, United States, is a wider shell with well developed ears and sparsely developed spines. *Quadratia patula* (Girty, 1915, p. 13, pl. 1, fig. 1-16, 2) from the Mississippian Boone Limestone of Arkansas, United States, is close in shape but has stronger and regular commarginal rugae in both valves, approaching those of *Plicatiferina* Kalashnikov, 1980, p. 15 from Kasimovian faunas of Bashkiria, Russia. *Q. alifera*

Fig. 24. *Quadralosia delicata* Waterhouse GSC 140220, from GSC loc. 53740, showing impressions of spine bases, strongest along the hinge as arrowed, x3,

Fig. 25. *Quadralosia delicata* Waterhouse, broken internal mould of immature dorsal valve GSC 140221, from GSC loc. 53743, showing subdued adductors, fine median septum and elongate pustules, x3,

(Girty, 1899, p. 530, pl. 68, fig. 10a-c) from the Madison Limestone of Yellowstone Park, Wyoming, shows more visible spines, subdued commarginal rugae and prominent alar extensions to the hinge. From the Chappel Limestone of late Kinderhookian and possibly early Osagean age in central Texas, *Quadratia egregia* Carter, 1967, p. 284, pl. 17, fig. 1a-8 has more marked commarginal rugae, and diductor scars are bordered each by a ventral marginal ridge extending from the umbo for half of the length of the shell (Carter 1967, pl. 17, fig. 5), diverging more narrowly than in type *Quadratia*. Dorsal spines are lacking.

Suborder LINOPRODUCTIDINA Waterhouse, 2013

Superfamily **PAUCISPINIFEROIDEA** Muir-Wood & Cooper, 1960

Family **YAKOVLEVIIDAE** Waterhouse, 1975

Subfamily **MUIRWOODIINAE** Waterhouse, 2018

Genus ***Muirwoodiciana*** n. gen.

Diagnosis: Medium-small in size with gently concavo-convex disc and long high trail at right angles, ornament of costae, row of hinge spines, strut spines placed at cardinal extremities and at least one pair one each side of anterior sulcus, but some specimens have additional stout spines in the sulcus, or over lateral flanks. Exceptionally for the family, the dorsal valve has a number of fine erect spines scattered over the anterior disc.

Type species: *Muirwoodiciana inexpectans* n. gen., n. sp. from the Blackie Formation at Peel River, OD. (See p. 108).

Muirwoodiciana n. sp.

Fig. 26, 27

Diagnosis: Wide shells with comparatively large ears, strut spine near each cardinal extremity, one or two pairs of sturdy moderately well defined spines anteriorly near sulcus. Fine dorsal spines over the anterior disc near the start of the trail. Well defined commarginal rugae over both valves.

Material: Two ventral valves, and two incomplete specimens with valves conjoined from GSC 53740 and a dorsal valve from GSC 53741.

Dimensions in mm: ventral valve, GSC locality 53740

Width	Length	Height
44	20	9

Description: The specimens are of moderate size for the genus, and transverse, with hinge at maximum width of the shell, and alate ears at the cardinal extremities, cardinal angle measuring 30^{o} to 40^{o}. The ventral umbo protrudes only slightly beyond the hinge, with an angle varying from 80^{o} to 100^{o}. The ventral valve is gently convex over the disc and extends into a trail at a high angle, and the dorsal disc is very gently concave, lying at approximately right angles to a long geniculate trail. The ventral sulcus commences a little in front of the umbonal tip and widens at 25^{o}, and persists over the trail, with little further expansion, and the dorsal fold is lower but reflects the ventral sulcus. Ventral ears are enrolled, and again, reflected by the dorsal ears. Both valves are entirely covered by ribs, ten in 5mm at 7mm from the umbonal tip, and not entirely equal in strength, those of the outer walls of the sulcus being slightly broader. Increase is by intercalation, with some outer ribs increasing by branching. Over the trail, there are six ribs in 5mm, but the number may vary slightly, and ribs

are a little finer over the dorsal disc, and ribs increase by branching. The anterior disc of both valves is crossed by low commarginal rugae, about three in 5mm. Ventral spines include a row just in front of the hinge, and no row along the umbonal slopes. A large spine lies on each ear, a little in front of the hinge, towards the anterior lateral margin of the ear. One or two prominent spines also occur each side of the sulcus towards the trail or over the trail, and further fine spines are scattered over the valve, with spines moderately numerous near the start of the trail, and rarely lying in short commarginal rows. A ginglymus may be developed along the hinge. Dorsal costae cover the valve, including the ears, and a few increase by branching. Fine erect spines lie over the valve, some scattered, some in incomplete commarginal rows over the median disc and trail.

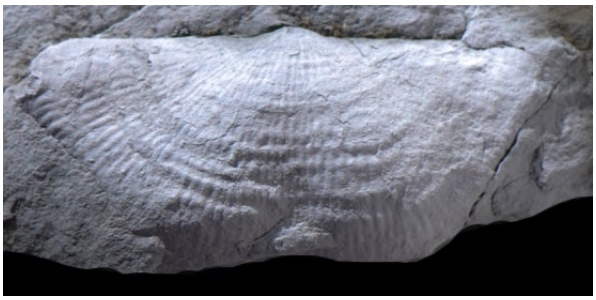


Fig. 26. *Muirwoodiciana* n. gen., n. sp., ventral valve GSC 140222 from GSC 53740, x2.

In the dorsal valve, there is a broad low platform in front of the cardinal process. Elongate narrow brachial shields are developed, bordered by low brachial ridges, and enclosing comparatively smooth though undulating shell. The lateral and anterior floor of the dorsal disc around the brachial shields is covered by dense pustules, and large pits are developed in rows along the interspaces between ribs over the dorsal trail.

Resemblances: Apart from the presence of fine dorsal spines, this species is close in some respects to *Sajakella* Nasikanova in Sarytcheva, 1968, originally described from the Keregetass Suite (?Bashkirian) of Kazakhstan. Several species, two a little younger, were assigned to this genus by Nasikanova and by Grigorieva in Sarytcheva (1968, pp. 41-43, pl. 19). If figures in that plate are relied on for interpreting the genus, there are two clear strut spines in one specimen, *Sajakella*? *martianovi* (Lapina), but only vague suggestions of possible strut spines in some of the other specimens. The Canadian species is moderately close to specimens of *S. formosa* Nasikanova that were figured by Klets (2005, pl. 11, fig. 13,

14) from mid-Carboniferous (Bashkirian) beds of south Verchoyan. These specimens have extended cardinal extremities each apparently bearing a strut spine, and an anterior pair of strut spines, with a further strut spine showing in between. The type specimens have better defined ribs and rugae, and are slightly less alate, and the distribution of spines is obscure. *Sajakella dzhinsetuensis* Lazarev, 1992 from the upper Visean of Mongolia is moderately alate (see Rozanov 2003, pl. 11, fig. 1-4) and shows well defined ornament, though the distribution of spines needs clarification.

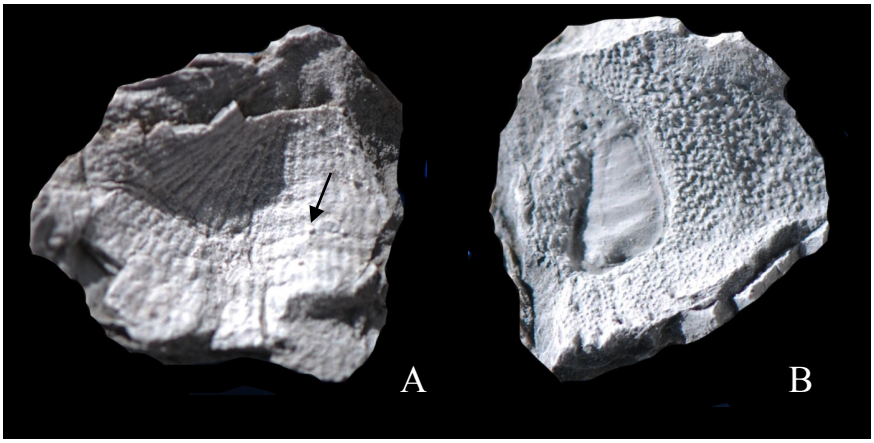


Fig. 27. *Muirwoodiciana* n. gen., n. sp., dorsal valves GSC 140223 and 140224. A, fragment of dorsal valve with posterior interior visible, showing scattered fine erect spines, with one arrowed. B, internal dorsal valve showing brachial shield. Specimens from GSC 53740, x3.

Superfamily **LINOPRODUCTOIDEA** Stehli, 1954

Family **GIGANTOPRODUCTIDAE** Muir-Wood & Cooper, 1960

Subfamily **MARGINIRUGINAE** Waterhouse, 2013

Diagnosis: Medium-sized to moderately large costellate shells with well formed row of ventral hinge spines and other usually anterior fine ventral spines, no dorsal spines. Dorsal valve with hinge ridge, lateral buttress plates or mounds, and ridges, no brachial cones, moderate to thin body corpus, short trail, may be subgeniculate.

Name genus: *Marginirugus* Sutton, 1938, p. 559 from the Keokuk Limestone of Missouri and Illinois (lower Visean), United States, OD.

Discussion: *Marginirugus* ranges from Lower Carboniferous (Visean) to Upper Carboniferous

(Bashkirian). The genus has linoproductoid ribbing, wide shallow-corpused disc and moderately developed trail, bearing a row of spines along the ventral hinge, and scattered ventral body spines that are generally erect although some do possess gently ramped bases (see Brunton et al. 2000, Fig. 315a, f); spines are erect anteriorly and over the trail. There are no dorsal spines. Adductor scars are strongly dendritic in both valves, and the cardinal process is trilobate in the type species *M. magnus* (Meek & Worthen, 1862, p. 142). A broad domal platform lies in front of the cardinal process, with pair of hinge ridges and there is a thick but not high marginal ridge. *Marginirugus* cf. *magnus* (Meek & Worthen) at the Natural History Museum, London, from 0.9mile south of My Judea, Arkansas, United States, shows small dendritic ventral adductors and weakly impressed almost smooth diductor scars in one specimen, and broad and striate diductor scars in another, in front of a small smooth non-pustuled floor each side of the dendritic adductors. Coarse pits also lie behind the diductors laterally, and fine pits lie in front over the floor of the valve, and seemingly over the posterior septum (Muir-Wood & Cooper 1960, pl. 116, fig. 4). There are short slender ridges which pass forward posterolaterally behind the adductor scars (Muir-Wood & Cooper 1960, p. 308, pl. 116, fig. 4, 7), and figures of *M. barringtonensis* (Dun, 1902, pl. 25, fig. 3, 5) and Campbell (1956, pl. 50, fig.11) from New South Wales, Australia, clearly indicate distinct lateral buttress plates, lying outside the posterior adductor scars. The dorsal interior is somewhat like that of Reticulumiinae Waterhouse, 2013, p. 162, a dictyoclostid subfamily, and also Tapajosiini Waterhouse, 2013, p. 362, a tribe within Linoproductidae, which is distinguished from the present tribe by having erect spines without prolonged bases. It is also close to further linoproductidin family groups Gigantoproductidae and Semiplaninae, and further inspection may confirm that the group displays spines like those of Wardlawriinae. Other than shape, many details within *Marginirugus* fall close to those of Semiplaninae, opening the possibility of tribal relationship. Against such affinities, there may be a case to considering a relationship to Balkhasheconchinae and Levipustulinae (see p. 97), because of the presence of dorsal buttress plates, but these subfamilies lack well developed radial ribbing, and so appear to have converged in their internal morphology of the interior of the dorsal valve.

Marginirugus Sutton was regarded as linoproductoid by Muir-Wood & Cooper (1960,

p. 317), and as Productini by Brunton et al. (2000). Schrenkiellidae shows some approach but lacks the posterior septal mound and buttress plates in the dorsal valve, and its ventral spine bases are not prolonged.

Genus ***Marginirugus*** Sutton, 1938

Diagnosis: Moderately large to medium-sized transverse costellate shells with well formed row of ventral hinge spines and other usually anterior fine ventral spines, no dorsal spines. Dorsal valve with hinge ridge, septal mound and lateral buttress plates, no brachial cones, moderate to thin body corpus, short trail, may be subgeniculate.

Type species: *Productus magnus* Meek & Worthen, 1862, p. 142 from Visean of Illinois, OD.

Marginirugus sp.

Fig. 28

Material: Three ventral valves and small dorsal valve from GSC 53740.

Description: The best preserved specimen measures 92mm wide, 52mm long and 12mm high. A small dorsal valve which appears to be juvenile or at very early maturity is 17mm wide, 8mm long and 3mm high. The ventral umbo is low and broad with an angle of 120°, scarcely protruding beyond the hinge, and the hinge is at maximum width, with inconspicuous but comparatively large gently convex ears, now damaged, and obtuse cardinal extremities. The valve is gently convex, without median sulcus, and with a very low trail at a high angle to the disc. The dorsal valve is gently concave with slightly more conspicuous and large concave ears, and no fold. The entire valve exterior, including ears, is covered by fine even narrow costellae with steep low sides, rounded crests and wide interspaces, some five to six in 5mm anteriorly, and increasing by intercalation on both valves. Weak growth lines and threads are strongest near the hinge and pronounced over the dorsal valve as low rugae. Slender spines form a row close to the ventral hinge, and are scattered especially over the anterior disc and posterior trail, with a few coarse spines at the ventral geniculation.

Resemblances: The type species *Marginirugus magnus* (Meek & Worthen) from the Keokuk Formation or equivalents of Illinois, well illustrated by Weller (1914, p. 117, pl. 15, fig. 1-8) and Muir-Wood & Cooper (1960, pl. 116, pl. 117), tends to be more elongate, and is slightly

more inflated, with more spines close to the ventral geniculation. The genus has also been recorded from the upper Burindi Group of Visean age in New South Wales, Australia, though overlooked by Brunton et al. (2000, p. 469). The taxa, described as *Productus barringtonensis* Dun, 1902, and *Marginirugus barringtonensis alatus* Campbell, 1956, are like the Illinois specimens but have coarser ribs. In Australia they were shown as overlapping uppermost Visean (Brigantian) and lower Namurian by Roberts (1985, Fig. 38) and Roberts et al. (1976), and it appears that the Canadian material could be close in age.

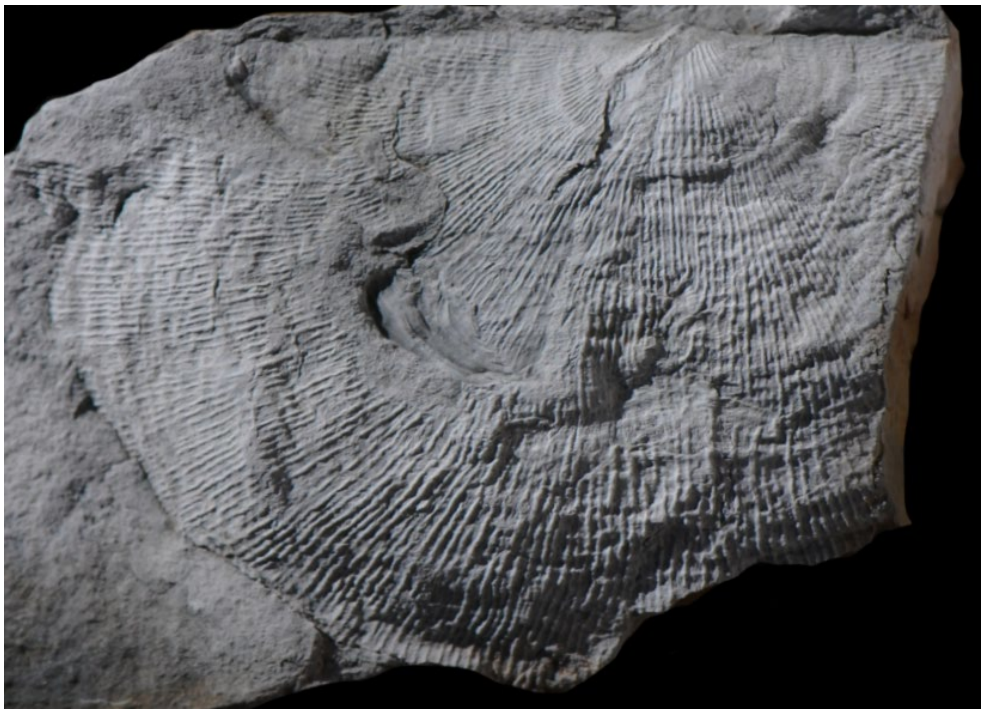


Fig. 28. *Marginirugus* sp., ventral valve GSC 140225 from GSC 53740, x2.

Superfamily **PROBOSCIDELLOIDEA** Muir-Wood & Cooper, 1960

Family **PAUCISPINAURIIDAE** Waterhouse, 1986

Subfamily **MAGNIPLICATININAE** Waterhouse, 2001

Tribe **MAGNIPLICATININI** Waterhouse, 2001

Subtribe **MAGNIPLICATININAI** Waterhouse, 2001

Magniplicatin gen. & sp. indet.

Fig. 29

Material: Three fragments of ventral valves from GSC 53740.

Description: The specimens are very incomplete and small, one measuring almost 17mm wide, and the other little larger. The specimens apart from the ears are covered by fine ribs, three in 1mm, and ventral spines lie over the disc with short subelongated and swollen bases, as well as the suggestion of a number of erect spines over the one ear that is preserved. The umbo is broad and low, and low irregular commarginal rugae cross the valve.

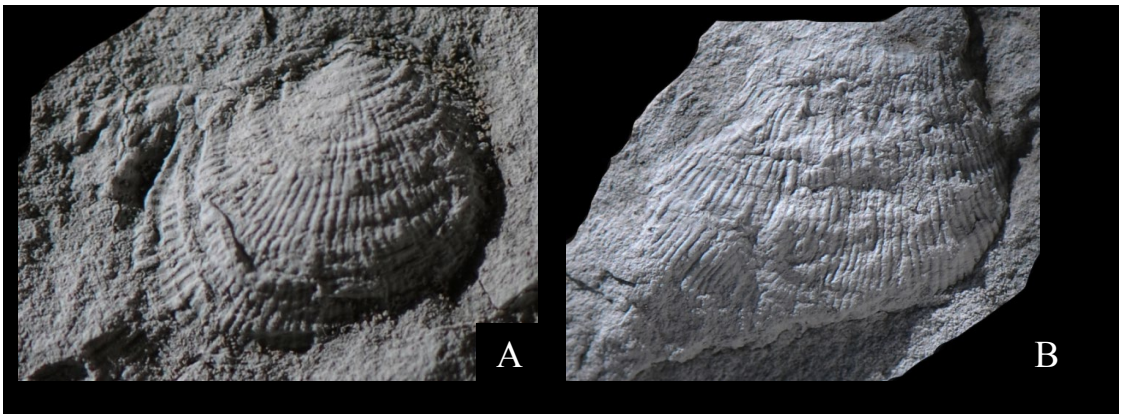


Fig. 29. Magniplicatin gen. & sp. indet. A, ventral valve GSC 140226, x5. B. ventral valve GSC 140227, x3. Specimens from GSC 53740.

Superorder RHYNCHONELLIFORMI Kuhn, 1949

Order RHYNCHONELLIDA Kuhn, 1949

Suborder RHYNCHONELLIDINA Kuhn, 1949

Superfamily **RHYNCHOPOROIDEA** Muir-Wood, 1955

Diagnosis: Shell endopunctate, costal interspaces may project into marginal spines.

Family **RHYNCHOPORIDAE** Muir-Wood, 1955

Diagnosis: Endopunctae simple or merging. Sulcus and fold variably developed, cardinal plate may enclose a well developed small septalium, which may be overlain by cover plate.

Subfamily **TRETORHYNCHIINAE** Savage, 2002b

Diagnosis: Endopunctae simple. Sulcus and fold well developed, costae simple. Ventral dental supports varied in strength and position. Anterior shell convergent. Cardinal platform

large, as a rule with short posterior septalium and no cover plate.

Discussion: Savage (2002b, p. 1233) separated Tretorhynchiinae new subfamily for *Tretorhynchia* Brunton, 1971, 1984, p. 36. Both Tretorhynchiinae and Rhynchoporiinae contained only one genus each at the time of the Savage analysis, and each was densely punctate. They have been associated with two subfamilies based on two distinctive genera with cup-shaped cardinal plate of upper Devonian extending into lower Tournaisian age, named by Erlanger, 1993. Tretorhynchiinae has a wide septalium, lacks the cover plate which has a posterior perforation as a rule, and lacks the high anterior shell at right angles to the commissure found in *Rhynchopora*.

Genus ***Tretorhynchia*** Brunton, 1971

Diagnosis: Subtriangular with biconvex shells, open delthyrium, both valves sulcate for much of length, numerous simple costae over entire shell, which is finely endopunctate. Short submedian dental plates, long dorsal median septum, broad septalium with broad cardinal plate, no cardinal process. With or without ventral foramen.

Type species: *Terebratula trilatera* de Koninck, 1843, p. 292, 1887, p. 50 from Visean of Belgium, OD.

Discussion: Brunton (1971, 1984) wrote nothing of a ventral foramen, whereas Koninck (1987, p. 50) recorded a small barely perceptible opening. He offered a substantial synonymy, not discussed by Brunton (1971, 1984).

Tretorhynchia? sp.

Fig. 30B

Material: A specimen with valves joined from GSC 53745.

Description: The specimen is small, about 15mm wide, and 5mm high, with valves conjoined. The ventral umbo is obscure, with foramen above open delthyrium. Costae are closely spaced with rounded crests. A moderately wide sulcus with angle of just over 25^{o} traverses the dorsal valve, and the shell is endopunctate.

Resemblances: This specimen is unusual because of the moderately well defined dorsal sulcus. It is endopunctate, like a species much more abundant in the Hart River outcrops, as

described below, but these specimens are readily distinguished by their well developed dorsal fold, as illustrated in Fig. 30A. An attempt to dissolve the shell and examine internal morphology was not particularly successful, other than showing that the dorsal septum is comparatively long, and the dental plates well defined posteriorly, as in *Tretorhynchia* and better defined than in the other Hart River species, called *Rhynchoporusia*. Specifically the Yukon specimen differs from *Tretorhynchia trilatera* having lower less angular costae, and in displaying a foramen.

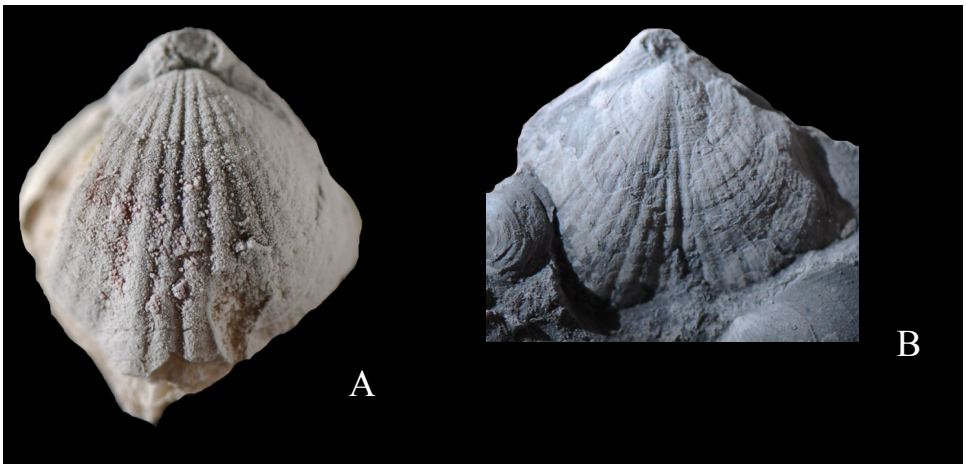


Fig. 30. A, *Rhynchoporusia multiplicata* n. gen., n. sp., conjoined specimen GSC 140230 from GSC 53743, showing broad dorsal fold. B, *Tretorhynchia*? sp. dorsal aspect of specimen with valves conjoined GSC 140238 from GSC 53745, showing long median doral sulcus and ventral foramen. Specimens x3.

Genus ***Rhynchoporusia*** n. gen.

Derivation: Name altered from genus name Rhynchopora.

Diagnosis: Shells closely or partially costate, finely punctate (or partly taleolate), sulcus and fold well developed. Foramen, dental plates very short if present and placed close to lateral walls, well formed cardinal plate divided by narrow posterior septalium, no cover plate.

Type species: *Rhynchoporusia multiplicata* n. gen, n. sp. from the Hart River Formation (late Mississippian) of Yukon Territory, here designated.

Discussion: At first sight, this genus appears to belong to *Rhynchopora*, because the shell is closely plicate and appears to be punctate. The type species from the Yukon Territory has

densely pitted inner shell, as illustrated in Fig. 32 and Fig. 36, although actual pores can seldom be clearly discerned, and the complexity in much of the shell structure could be due to taleolae rather than punctae (Kozlowski 1929, Williams 1956). *Rhynchopora* is definitely punctate, based on *Terebratula geinitziana* Verneuil, 1845, p. 83 from north Dvina River Basin (Kazanian), Russia. It is widespread, having been reported from Carboniferous and Permian deposits from over much of the globe. There has been a difference of opinion over the cardinalia in *Rhynchopora*. Hall & Clarke (1894) and Kozlowski (1914) claimed that the hinge (or cardinal) plate was divided, whereas Weller (1910, 1914) reported an undivided plate, and Licharew (1925, p. 115, pl. 2, fig. 8, 12) demonstrated that the cardinal plate in the type species, *R. geinitziana* (Verneuil), was undivided. The difference seems genuine.

Large suites externally like *Rhynchopora* were described and so identified by Cooper & Grant (1976) from the Glass Mountains of Texas. In all, the septalium is covered by a plate with posterior foramen. Otherwise they show some variation. In one fragment ascribed to *R. hebetata* Cooper & Grant (1976, pl. 694, fig. 78), there appears to be a distinct median trough, and questions may be raised about other specimens, such as those figured as *R. palumbula* Cooper & Grant (1976, pl. 696, fig. 12, 13, pl. 697, fig. 3). Understanding is not helped by the small size of the figures, and the overexposed nature of many of the illustrations. *Rhynchopora youngii* Davidson (1880, p. 286, pl. 33, fig. 11, 11a, b, c) differs again, with smooth umbonal region and no high anterior shell, from upper Visean or Serpukhovian faunas of Ayrshire, Scotland. This is a new genus, but its interior is not known.

In some specimens amongst present material, a small septalium is strongly suggested, as illustrated in Fig. 33C, D, which shows a well developed septalium at the posterior end of a moderately large cardinal plate. The Yukon material appears to be identical with specimens from the Moorefield Shale of Arkansas, as described by Girty (1911), although Girty did not report definite punctation, considering that the suggestion of such a feature was due to oblique fibres in the shell (Girty 1911, p. 56). One well preserved dorsal internal mould illustrated by Girty (1911, pl. 7, fig. 16) for *Liorhynchus carboniferum* illustrates a tiny median trough in the cardinal plate between the dental sockets. The interior thus approaches that of *Pugnoides* Weller, 1910, p. 512, which is moderately close externally,

though it is impunctate, with better developed dental plates and massive dorsal septum in the type species, *Rhynchonella ottumwa* White, 1865, p. 23. This genus is from Visean of North America, and classed in Petasmariidae Savage, 1996 (Savage 2002a).

Muscle scars could also prove to be of significance. Cooper & Grant (1976b) described muscle scars for Glass Mountains *Rhynchopora*, but their figures give only generalized impressions, and no detailed line drawings were provided. Muscle scars are not clearly defined in *Rhynchoporusia*, but are well shown by Girty (1911, pl. 7, fig. 13, 15) in material that might be allied to the Canadian genus.

Tretorhynchia Brunton, 1971 was erected for Visean shells from Belgium, Ireland and England that bears very fine endopunctae. No cardinal process was developed, and the sulcus and fold are lacking anteriorly, with a rectimarginate anterior commissure, though a dorsal sulcus occupies much of the valve (Brunton 1984, Fig. 16, 17a). The septalium is wide and the cardinal plate is virtually absent in some figures presented by Brunton (1971) and by Savage (2002a), but better preserved material illustrated by Brunton (1984, Fig. 9A, B) shows a wide shallow septalium in the middle of a cardinal plate. The anterior shell of each valve converges on that of the opposing valve, unlike the steep high anterior margins at right angles to each other in type *Rhynchopora* (see Licharew 1960, pl. 52, fig. 15v), which has a foramen, whereas no mention was made of a foramen in the Brunton accounts.

In the Canadian material, the ventral sulcus and dorsal fold are comparatively well developed, especially in one subset of specimens, and plicae are more rounded and less angular than in many *Rhynchopora*, or type *Tretorhynchia* or *Rhynchopora youngii* Davidson, but anterior margins are convergent as in the two latter forms. The presence or absence of a cardinal process cannot be clearly ascertained for *Rhynchoporusia*. Unlike the European or most United States species assigned to *Rhynchopora*, the morphologies displayed amongst Yukon specimens show a considerable range, from moderately plicate to almost smooth, and from sulcate to again, almost smooth. In these aspects of morphology the Canadian specimens agree with the suite of much the same age described by Girty (1911) from the Moorefield Formation of Arkansas, and the much greater morphological range, notably the variation in strength of costation, arguably suggests a distinct generic position within the spectrum of the subfamily. In this study, the largest and consistently plicate shells are treated

as belonging to the same taxon as the smaller and more numerous and variable specimens, which are not quite well enough preserved to allow evaluation of the possibility that they belong to a separate taxon. Girty (1911) had referred his material to *Liorhynchus* Hall, 1860, now *Leiorhynchus* Hall, a Devonian member of Camaroechioidea, but Girty's material lacks the strong median dorsal septum of that genus.

The Canadian genus is further distinguished by the poor development of the plates supporting the teeth. Only some of the specimens indicate short plates, placed close to the lateral walls, with the cavity between plate and wall tending to be infilled with callus. Girty's material from the Moorefield Shale is much the same. A number of the Canadian specimens show no dental plates at all, and possibly this is due to imperfect preservation, although they possibly could have lacked plates. The plates are much less developed than those typical of *Rhynchopora*, or in the new allied genus *Mysteronia*, as described on pp. 116 and 117 from the Blackie Formation.

Rhynchoporusia multiplicata n. sp.

Fig. 30A, 31 - 38

1961a *Leiorhynchus carboniferum* (not Girty) – Nelson, pl. 1, fig. 1a-d.
1961b *L. carboniferum* (not Girty) – Nelson, p. 3.
1971 "*Leiorhynchus*" cf. *carboniferum* (not Girty) – Bamber & Waterhouse, p. 114, pl. 1, fig. 9, 10.

Derivation: multi – many, plica – fold, Lat.

Diagnosis: Small oval shells with shell mostly or all covered by about twenty five to thirty costae, a few specimens with few costae, shallow sulcus with three to eight costae, and low costate fold, both anteriorly placed. Anterior part of the two valves gently convergent, not at high angle to each other. Small terminal foramen, and short small dental plates. Small septalium, no cover plate. Apparent pores through inner shell opening into the interior, many possibly calcite-filled as in taleolae.

Holotype: Specimen GSC 140228 illustrated in Fig. 31A, here designated.

Material: Two specimens with valves conjoined from GSC 53743 and 53744, and eleven specimens with valves conjoined and four ventral valves from GSC 53745 make up the set of larger specimens. Smaller specimens are much more numerous, and include two ventral valves from GSC 53690 (but see p. 185**)**, two ventral valves from GSC 53743, sixteen ventral

valves, eleven dorsal valves and five specimens with additional fragments from GSC 53747, and one specimen with valves conjoined from GSC 53749.

Dimensions in mm:

Width	Length	Height
GSC 53747		
17	15	4
21	18	
16	14	
17	17.5	
22	20	

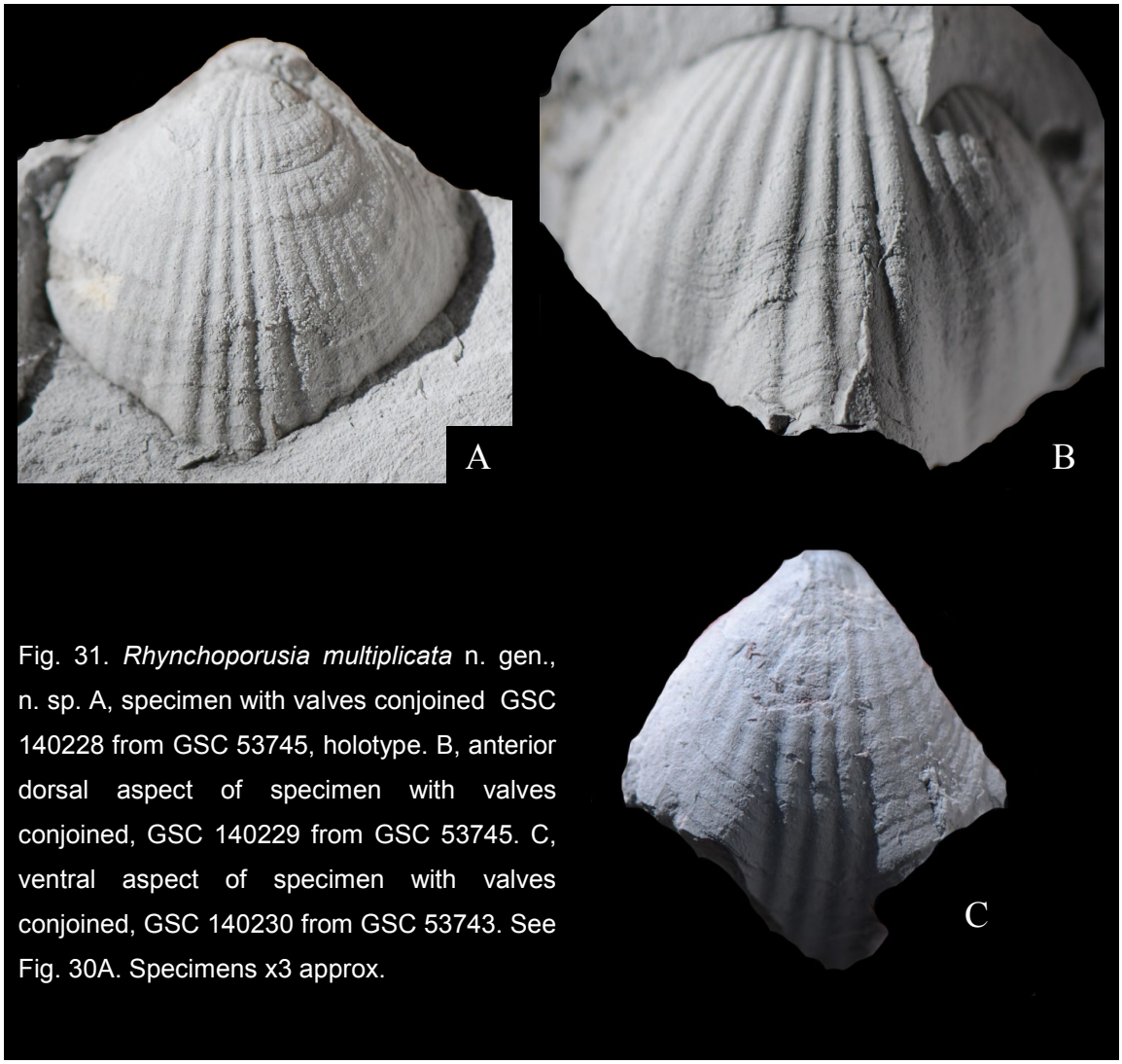


Fig. 31. *Rhynchoporusia multiplicata* n. gen., n. sp. A, specimen with valves conjoined GSC 140228 from GSC 53745, holotype. B, anterior dorsal aspect of specimen with valves conjoined, GSC 140229 from GSC 53745. C, ventral aspect of specimen with valves conjoined, GSC 140230 from GSC 53743. See Fig. 30A. Specimens x3 approx.

Description: Specimens of moderate size, the largest 26mm wide and 18mm high and another specimen 19mm wide, 18mm long and 12mm high. In front of the terminal foramen, the ventral posterior walls diverge at 90^{o}, and extend to obtuse cardinal extremities, and the much broader dorsal umbo fits snugly into the upper edge of the delthyrium, with poorly

preserved foramen. The ventral sulcus commences a little before mid-length, with a broad flatly concave floor, and is matched by a dorsal fold: both are well defined, with the ventral sulcus extending well forward, and the dorsal fold becoming more elevated anteriorly. Costae on specimens from GSC 53745 number three, four or rarely five over the fold and three or sometimes four in the sulcus, with five up to six costae each side of the fold, and extensive lateral smooth shell marked only by fine growth increments. The crests are rounded and there is no branching.

Many specimens are small and slightly squashed, numerous and crowded, with counts understating the number present. Specimens are little inflated and therefore appear to be at early maturity, and certainly not at late maturity. The ratio of width to length varies a little, and the ventral umbo is prominent, generally at an angle of 95^{o} to 105^{o}, with a small foramen exposed on some specimens, and the dorsal umbo is broader. Cardinal extremities are well rounded. Although the shells have been squashed, the umbonal portion some 5mm wide remains convex, possibly because of secondary or post-burial umbonal filling by calcite. A wide sulcus with gently concave floor lies over the anterior half of larger specimens, matched by a low broad fold on dorsal valves. Six to eight round-crested costae lie within the sulcus, and a slightly lower number to each side, and in most specimens the costae arise at or close to the umbonal tip, and the interspaces are matched by dorsal costae. The number varies a little, and on some specimens the costae are faint or absent over the posterior shell (see Fig. 37). The external surface is covered by very fine and closely spaced growth laminae, with stronger laminae at intervals, not visibly pierced by punctae, and in some shells bearing traces of fine radial fila. The median shell layer is pierced by what are either punctae or taleolae, numbering about ten in 1mm anteriorly even on large specimens (Fig. 32, 36).

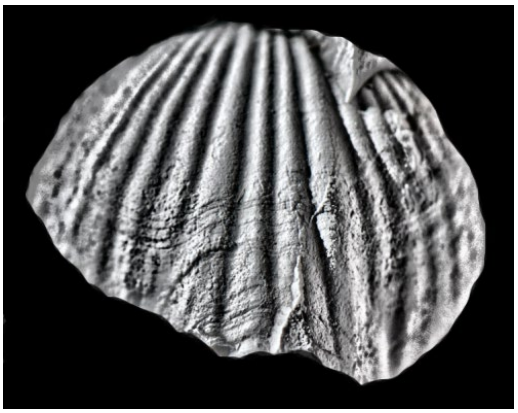


Fig. 32. *Rhynchoporusia multiplicata* n. gen., n. sp., anterior dorsal aspect of specimen with valves conjoined, GSC 140229 from GSC 53745, showing apparent punctae, x2.5. Reproduced by local equalization, see also Fig. 31B.

Rarely, fine rounded pores are visible, but this is exceptional, and possibly the tiny tubes are filled with calcite, approaching what have been called taleolae (Kozlowski 1929, Williams 1956). They pierce the thick median shell as far as the interior body cavity.

Teeth are cytromadont. Dental supports lie some distance from the ventral beak, and are comparatively short. Some specimens do not indicate any such plates, possibly because the cavity between them and lateral walls later became infilled with callus. The foramen is of moderate size, and as a rule poorly preserved.

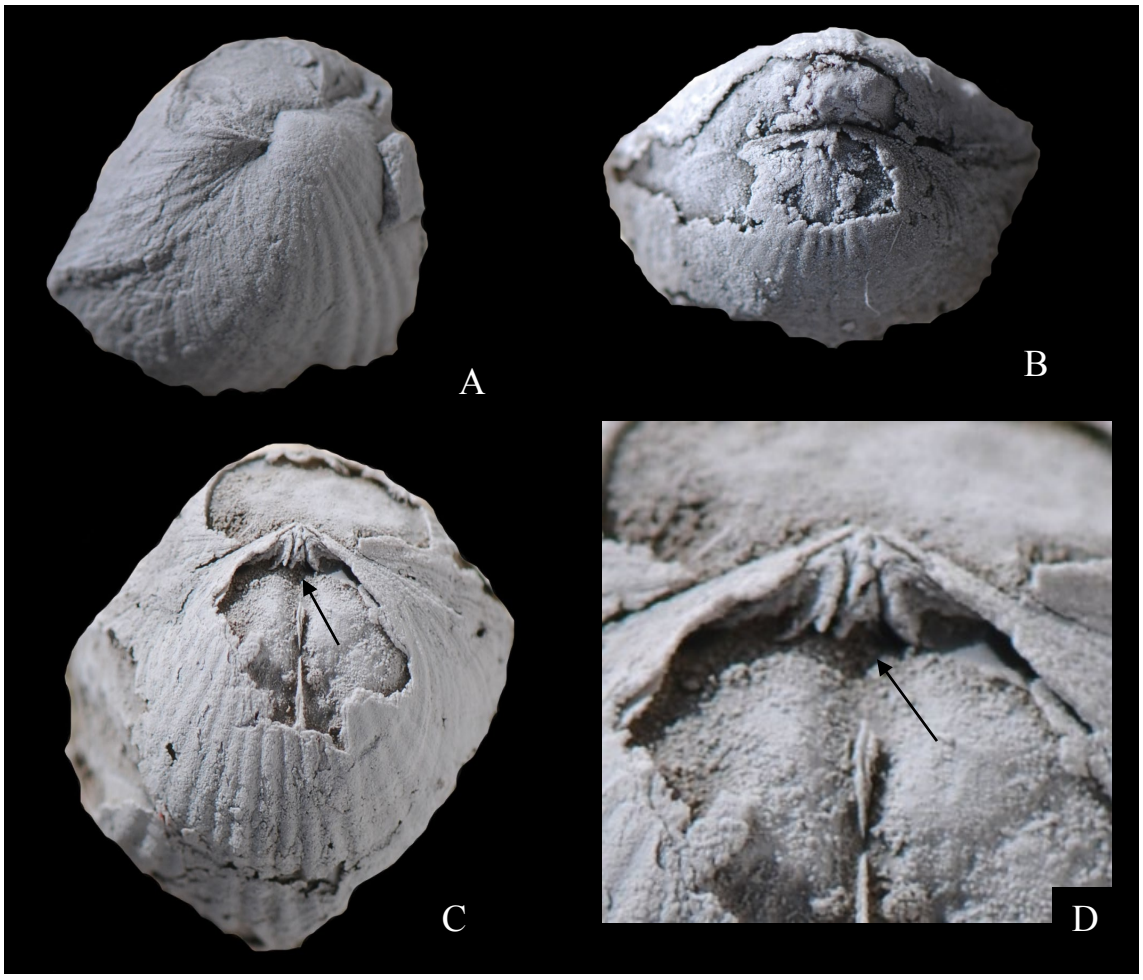


Fig. 33. *Rhynchoporusia multiplicata* n. gen., n. sp. A, oblique view of specimen GSC 140231, showing dorsal umbo, and worn ventral umbo. B, posterior aspect of specimen with valves partly etched, GSC 140232. C, posterior aspect of specimen GSC 140233, dorsal valve below, showing dental sockets and what appears to be the underside of a small septalium, arrowed. D, enlargement of dorsal cardinalia, showing arrowed possible septalium. Note divided median septum in front. Specimens with valves conjoined, from GSC 53745, x3, except D, x6.

A low dorsal septum extends for up to half of the length of the dorsal valve. It supports a short broad flat or gently and ventrally concave cardinal plate, which posterorly between the dental sockets bears a very small septalium (Fig. 33C, D). There are no definite muscle scars, and internal detail is poorly exposed, with a number of shells infilled with secondary calcite.

Resemblances: Nelson (1961a, pl. 1, fig. 1a-d) recorded a specimen with few costae as *Leiorhynchus carboniferum* from what he called Calico Bluff beds of the Yukon Territory, before the extensive revision of stratigraphy in Bamber & Waterhouse (1971).

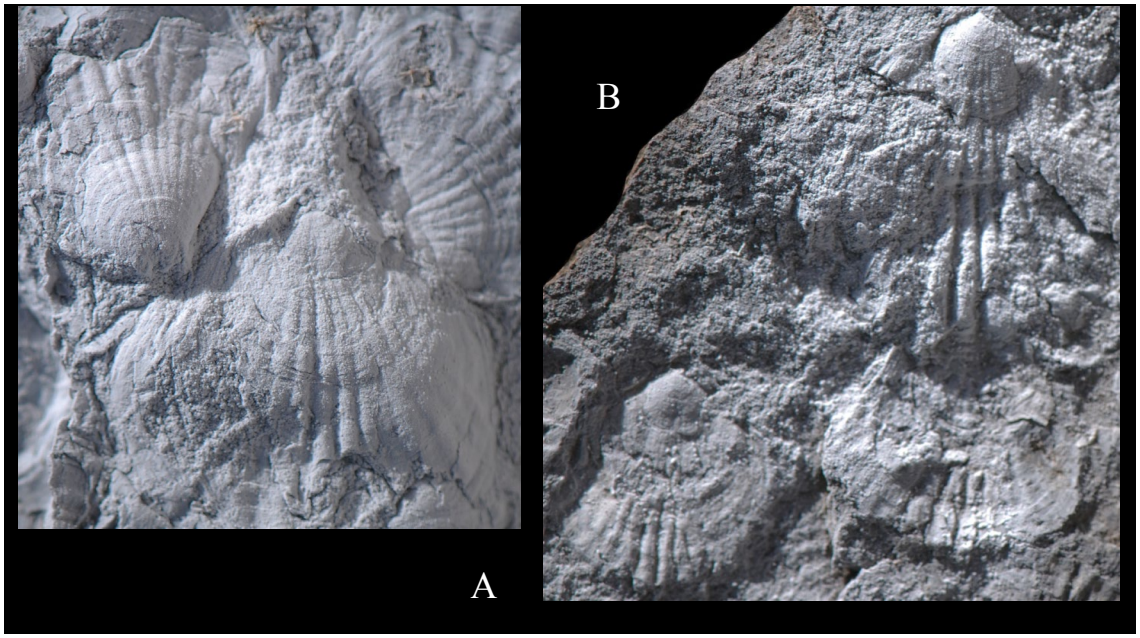


Fig. 34. *Rhynchoporusia multiplicata* n. gen., n. sp. A, small slab GSC 140234 showing specimens from GSC 53747. B, slab GSC 140235 from GSC 53747. Specimens x3.

These specimens are close in a general way to the material from the Moorefield Shale of Arkansas that were assigned to *Liorhynchus carboniferum polypleurum* Girty (1911, pl. 7, fig. 7-12), which was distinguished from *L. carboniferum* Girty, 1911 by having a costate posterior. Girty (1911) recorded two short and laterally placed dental plates for the principal species, and a long dorsal median septum, and illustrated a foramen as well as clearly defined muscle impressions in both valves. The Girty material is distinguished from the Canadian shells by having fewer ribs, about twenty or so, compared with twenty five to thirty

in the Canadian form. The interior of *polypleurum* is not entirely clear, although possibly the internal mould figured in pl. 7, fig. 11 might indicate a septalium with median ridge, or wide

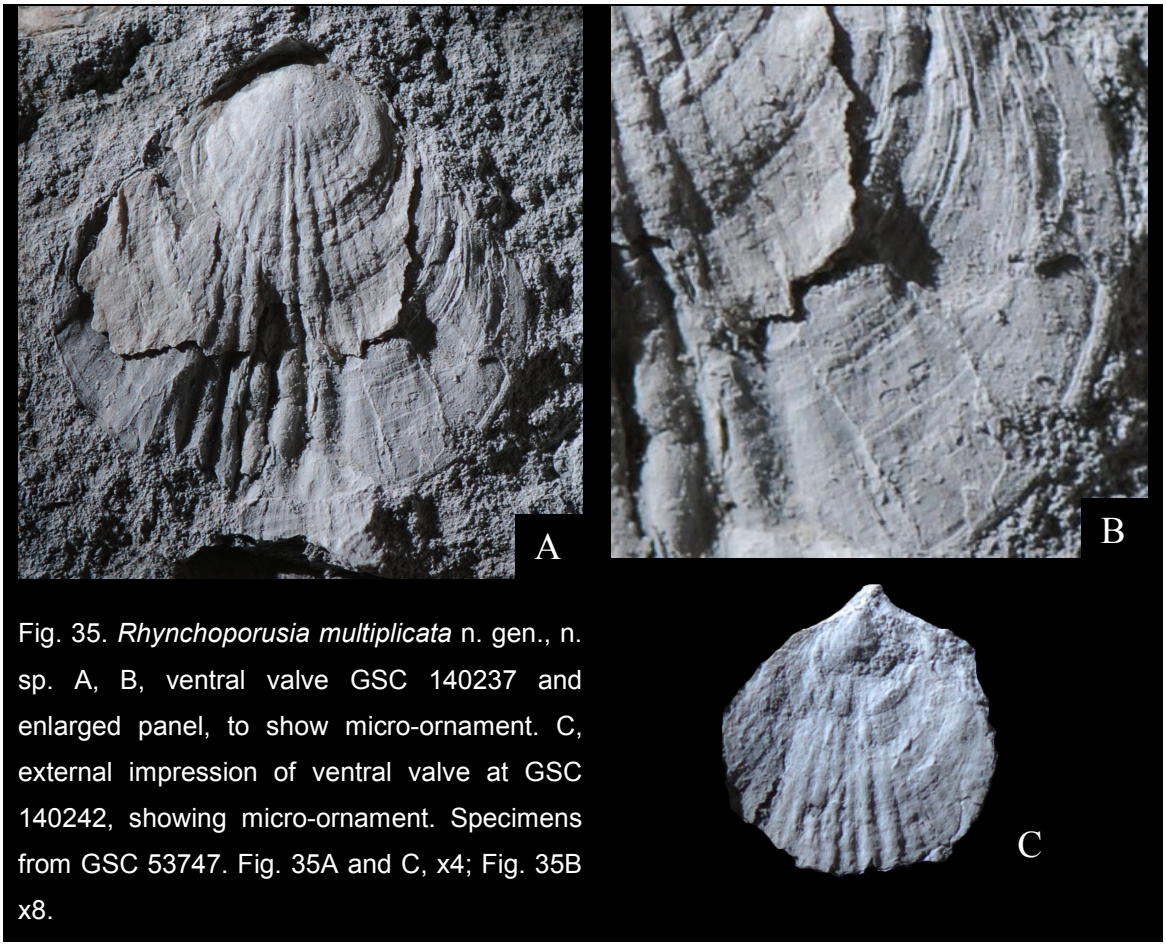


Fig. 35. *Rhynchoporusia multiplicata* n. gen., n. sp. A, B, ventral valve GSC 140237 and enlarged panel, to show micro-ornament. C, external impression of ventral valve at GSC 140242, showing micro-ornament. Specimens from GSC 53747. Fig. 35A and C, x4; Fig. 35B x8.

cardinal plate with narrow septalium. Girty (1911) also judged that *polypleurum* was represented in the Caney Shale of Oklahoma. The large and paucicostate shell described as *Liorhynchus carboniferum* Girty (1911, p. 54, pl. 7, fig 13-16) in the same fauna has a dorsal septalium and large cardinal plate (Girty 1911, pl. 7, fig. 16).

Shells described as *Rhynchopora sansabensis* Carter (1967, p. 314, pl. 26, fig. 1a-8b, text-fig. 8, 9) have a wider ventral sulcus and almost as many ribs as on the Canadian form, with well formed septalium. But unlike the Canadian material, or Girty's *Liorhynchus*, there is high anterior shell and cover plate, whereas the Canadian material has an anterior commissure and anterior shell more as in Stenoscismatidina and *Tetrorhynchia*.

Pugnoides ottumwa (White, 1865, p. 230 from Meramecian of Iowa is a little less rounded in outline, and the suite from the St Genevieve Limestone of Illinois figured by Weller

Fig. 36. *Rhynchoporusia multiplicata* n. gen., n. sp., dorsal valve GSC 140239 from GSC 53745, x5, to show the apparent pores in the shell.

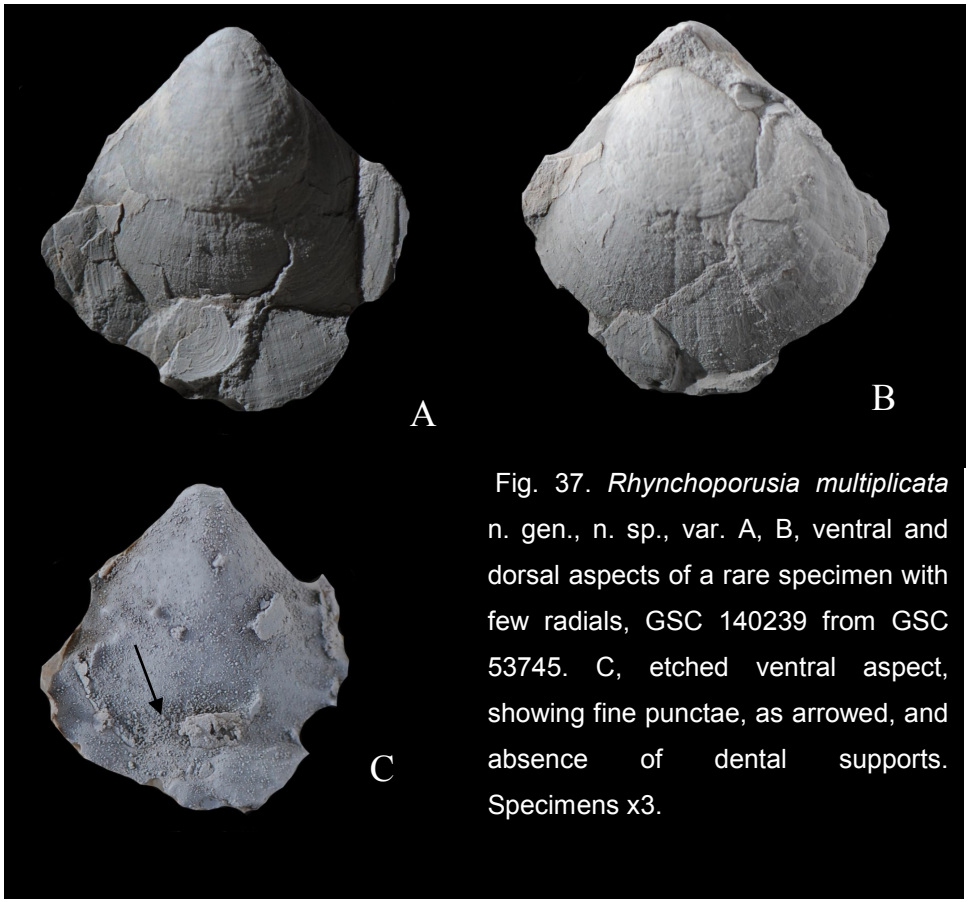


Fig. 37. *Rhynchoporusia multiplicata* n. gen., n. sp., var. A, B, ventral and dorsal aspects of a rare specimen with few radials, GSC 140239 from GSC 53745. C, etched ventral aspect, showing fine punctae, as arrowed, and absence of dental supports. Specimens x3.

(1914, p. 193, pl. 25, fig. 7-17, text-fig. 9) includes specimens with costae that cover much of the valve and others that are more limited to the anterior shell. Members of this genus are not punctate, and so approach the assessment of the Moorefield shells by Girty (1911). Sartenaer (1964) provided serial sections of the interior, to show a tiny septalium. *P. parvulus* Girty (1927, p. 414, pl. 23, fig. 34-44) from the Brazer Limestone of Idaho has relatively coarse costae, half the number of the present species, over all or much of the shell.

Another species *Pugnoides boonensis* (Shumard, 1855, p. 205, pl. C, fig. 6a, b), also figured by Hall & Clarke (1895, pl. 60, fig. 35) and by Weller (1914, p. 195, pl. 25, fig. 22-26) from the Fern Glen Formation and lower Burlington Limestone, is a larger smoother shell with a few strong costae limited to the anterior sulcus and fold. It arguably approaches *Liorhynchus carboniferum* Girty (1911, p. 54, pl. 6, fig. 1-8, pl. 7, fig. 13-16) from the Moorefield Shale of Arkansas, and reported from Nevada and Oklahoma. *P. triangularis* Mather (1915, p. 175, pl. 12, fig. 12; Murphy, 1954, p. 33, pl. 3, fig. 1a-e) is somewhat similar. Murphy's material came from Morrowan rocks in Utah.

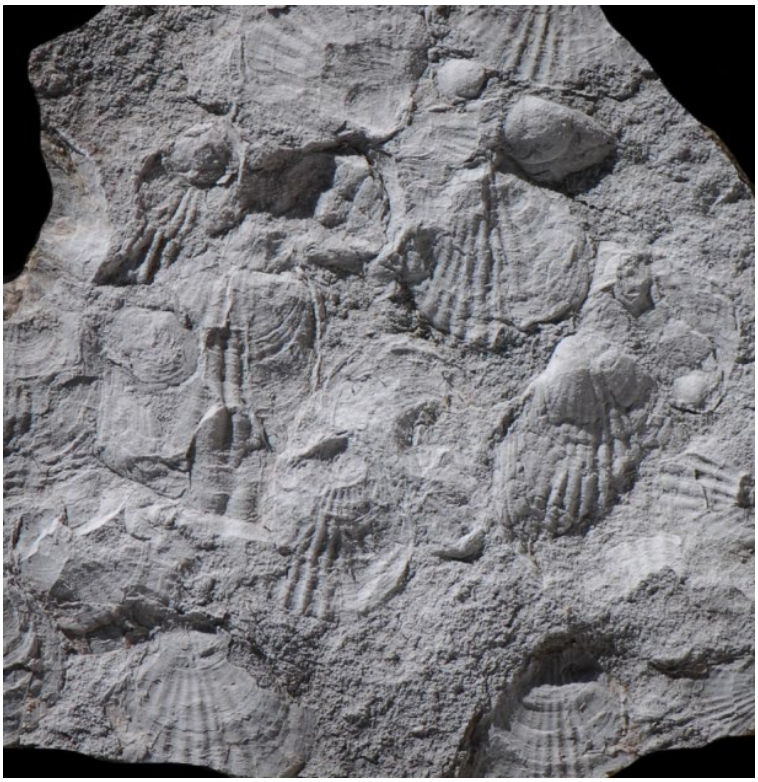


Fig. 38. *Rhynchoporusia multiplicata* n. gen., n. sp., small slab showing specimens GSC 140241 from GSC 53747, x3.

Superorder SPIRIFERIFORMI Waagen, 1883

Order SPIRIFERIDA Waagen, 1883

Suborder MARTINIIDINA Waterhouse, 2016

Infrasuborder MARTINIIMORHI Waterhouse, 2016

Superfamily **MARTINIOIDEA** Waagen, 1883

Superfamily **MARTINIIDAE** Waagen, 1883

Subfamily **MARTINIINAE** Waagen, 1883

Martiniin gen. & sp. indet.

Fig. 39

?1911 *Martinia glabra*? [not Martin] – Girty, p. 70, pl. 9, fig. 9-11.
?1911 *Martinia* sp. Girty, p. 72, pl. 9, fig. 8.
1971 *Martinia* sp. Bamber & Waterhouse, p. 114, pl. 1, fig. 14.

Material: An incomplete ventral valve from GSC 53742.

Description: The specimen is part of a valve originally 30mm wide, 22.5mm long, but broken, and 5mm high. A broad shallow sulcus arises before mid-length, with flat floor occupied by four round-crested low costae, and a very faint rib over each sulcal flank. There are five very low costae on the preserved lateral flank. In addition, fine radial lira cover the shell, crossed by fine growth increments over the entire shell, counted at ten in 1mm anteriorly, to give a very delicate cancellate micro-ornament.

The posterior shell has been lost to show a rhomboid muscle field, with narrow

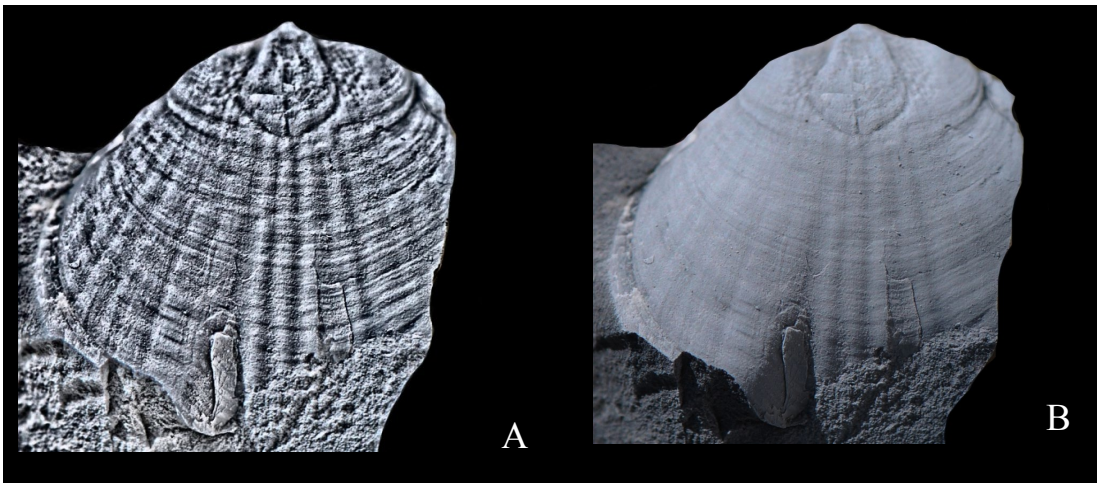


Fig. 39. Martiniin gen. & sp. indet., ventral valve GSC 140243 from GSC 53742 x3. A shows the same aspect as B, and has been processed by local equalization.

adductor scars, broadest posteriorly, and longitudinally striate diductor scars. Laterally the posterior shell has been slightly thickened, and bears shallow dimples.

Resemblances: One of the Moorefield specimens assigned to *Martinia glabra*? shows subdued lateral costae (Girty 1911, pl. 9, fig. 10), to suggest a possible relationship to the specimen from the Hart River Formation, though it must be allowed that the sulcus is more restricted than in the present specimen. Girty (1911) was unsure about the nature of the interior, and speculated about the possible presence or absence of what are now called adminicula, as ventral plates which rest on the floor of the valve. So there is no security about the identity of the Moorefield specimens with the present ventral valve. A small globular specimen of *Martinia* with visible ribs was reported from GSC 53760 of the Hart River Formation at section 116I-6 at Eagle River by Bamber & Waterhouse (1971, pl. 1, fig. 14; see also Bamber 1972, p. 115).

Infrasuborder CHORISTITIMORPHI Waterhouse, 2016

Superfamily **CHORISTITOIDEA** Waterhouse, 1968b

Choristitoid gen. & sp. indet. A

Fig. 40

Material: Two ventral valves, a small distorted dorsal valve and fragments from GSC 53740.

Description: The ventral valves are typical choristitids, possibly belonging to *Choristites*, but little is known of the interior, and the dorsal valve is obscure, so that the absence of tabellae cannot be ascertained. Micro-ornament is cancellate. One of the valves is 75mm wide.

Resemblances: A choristitoid species was described from the Moorefield Shale of Arkansas as *Spirifer arkansanus* Girty (1911, p. 66, pl. 8, fig. 2-4), and the present specimens could well be conspecific. But the Arkansas specimens are not well known, and the present specimens even more obscure.

Smaller specimens with finer ribs from the Hart River Formation were illustrated by Bamber & Waterhouse (1971, pl. 1, fig. 13, 16) from GSC 53760 at section 116I-6, Eagle River, and from GSC 53739 at section 116H-1B, Peel River (Bamber 1972, p. 109). The larger of the two figured specimens figured herein is close in size and shape to *Choristites praepavlovi* Semichatova (1941, *in* Stepanov et al. 1975, p. 195, pl. 89, fig. 4) from the

Bashkirian Zapadnogo beds of the Urals in Russia. There are also general similarities to *C. bisulcatiformis bisulcatiformis* Semichatova (1941, pp. 29-34, pl. 1, fig. 1, 2, 4, 6, pl. 8, fig. 1, text-fig. 14; 1969, p. 165, pl. 2, fig. 4-6, pl. 3, fig. 1) and varieties or subspecies from Bashkirian beds of the Russian Platform.

Furthermore, the type species of *Parachoristites* Barchatova, 1968, is similarly transverse, and this genus has short tabellae, indicating a position in Junglelominae Waterhouse within Palaeochoristitidae Carter in Carter et al., 1994 (see Waterhouse 2016, p. 130ff). But the dorsal interior is not known for present material, so that its subfamilial and generic position are not known.

Fig. 40. Choristitoid gen. & sp. indet. A. A, ventral valve GSC 140244. B, ventral valve GSC 140245. Specimens from GSC 53740 x1.

Infrasuborder AMBOCOELIIMORPHI Waterhouse, 2016

Superfamily **AMBOCOELIOIDEA** George, 1931

Family **AMBOCOELIIDAE** George, 1931

Subfamily **ATTENUOCURVIINAE** Waterhouse, 2010

Tribe **OGILVIECOELIINI** Waterhouse, 2016

Genus ***Hartea*** n. gen.

Derivation: Named from Hart River, Yukon Territory.

Diagnosis: Small-medium in size, ventribiconvex and narrowly bisulcate, micro-ornament of dense pustules and subfusc numerous fine radial ribs, long low ventral adductor ridges, no dental plates; no cardinal plate, short well formed tabellae, three coils in spire.

Type species: *Hartea venustus* n. sp., from Hart River Formation (upper Visean) of Yukon Territory, here designated.

Discussion: This genus is close in a number of respects to *Ogilviecoelia* Shi & Waterhouse, as interpreted by Waterhouse (2018), found in the early Permian members of the Jungle Creek Formation of the Yukon Territory, but has a more consistently convex dorsal valve, and a micro-ornament of fine pustules and fine close-set especially dorsal radial ribs rather than few if any well-spaced ribs and dense dimples or pits that help characterize the ornament in *Ogilviecoelia*. The presence of tabellae and lack of cardinal plate indicate likely tribal to subfamilial links, and one specimen partly etched in dilute hydrochloric acid shows four coils in the spire on one side. The spire has five to six coils in *Ogilviecoelia*. Members of Attenuocurviini Waterhouse are close in the nature of their dorsal cardinalia, but have a truncated spire with only one incomplete whorl each side, and the shell is small with highly inflated ventral valve. Micro-ornament in Attenuocurvini is close, but spines are stronger and

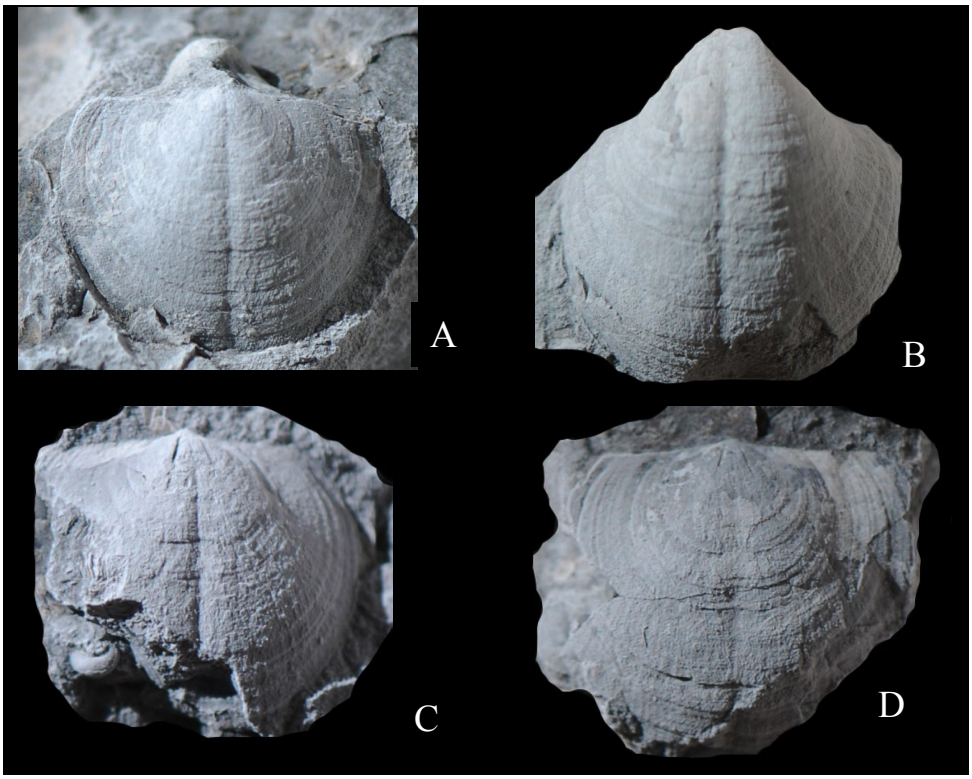


Fig. 41. *Hartea venustus* n. gen., n. sp. A, ventral view of GSC 140246 with valves conjoined from GSC 53745. B, ventral valve 140247 from GSC 53745. C, dorsal valve GSC 140248 showing tabellae, from GSC loc. 53743. D, dorsal valve GSC 140249 showing tabellae, from GSC 53743. Specimens x4.

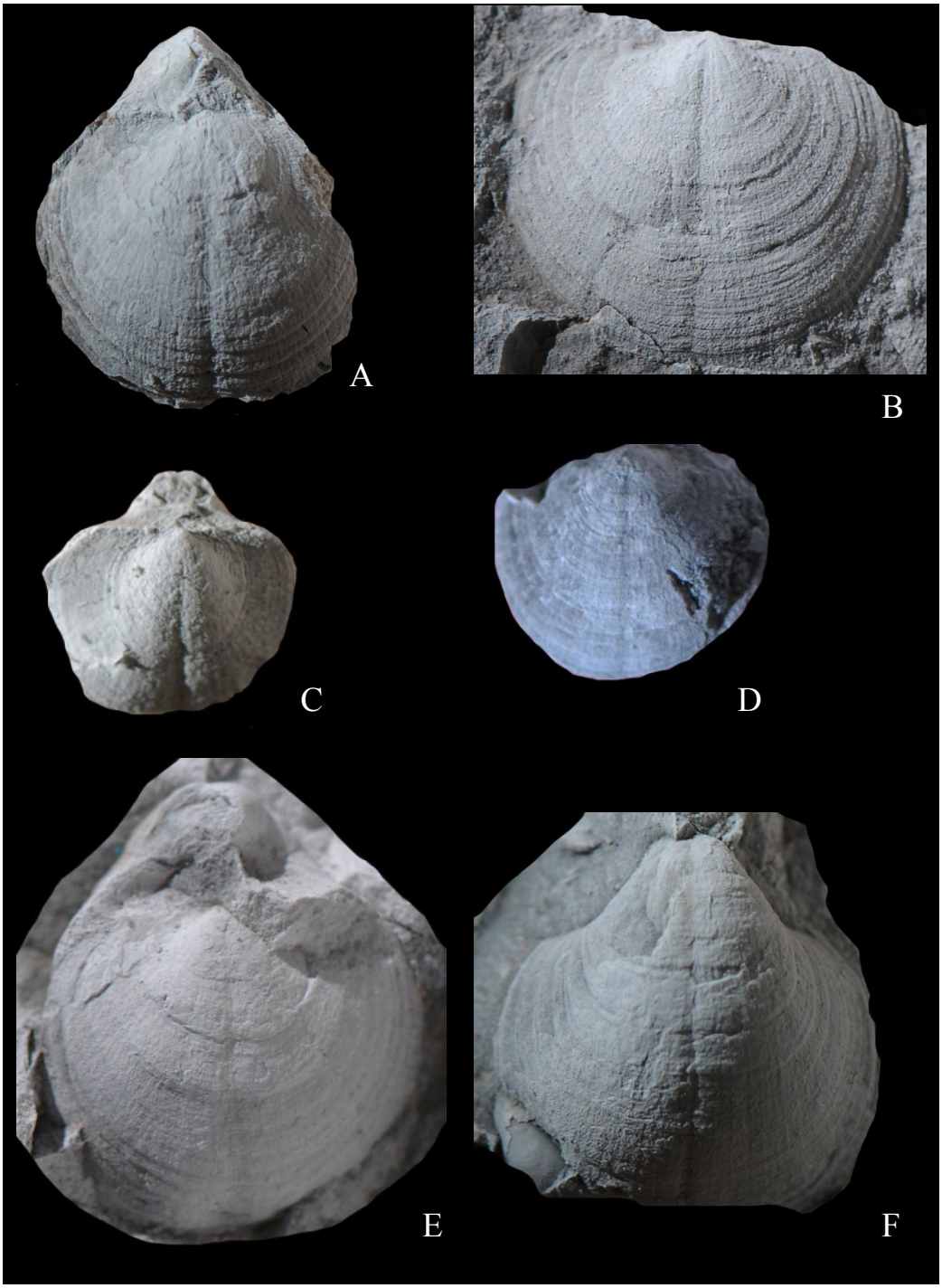


Fig. 42. *Hartea venustus* n. gen., n. sp. A, dorsal aspect of specimen with valves conjoined, GSC 140250 from GSC 53745. B, dorsal valve GSC 140251 from GSC 53749, showing the fine ribs that appear in decorticated shells. C, dorsal aspect of specimen with valves conjoined, GSC 140252 from GSC 53744. D, dorsal valve GSC 140253 from GSC 53747. E, dorsal aspect of specimen with valves conjoined, holotype, GSC 140254 from GSC 53749. F, dorsal valve GSC 140255 from GSC 53745. Specimens x4.

and fewer, and dorsal valves tend to be concave, or convexo-concave, and the tabellae of the dorsal valve are lower and less conspicuous.

The genus *Echinocoelia* Cooper & Williams, 1935 of Middle Devonian age in United States, and possibly Russia as the junior synonym *Pyramina* Liashenko, 1969, according to Johnson et al. 2006, p. 1736, shows similarities, with plates, uncertain tabellae, and micro-ornament of spines and commarginal growth-lines. An apical plate lies over the delthyrium. The ventral valve is highly inflated with attenuated ventral umbo, and little inflated dorsal valve.

Genera which display a micro-ornament of fine pustules are comparatively few, and include *Cruricella* Grant, 1976 based on a species from the early mid-Permian of Thailand, and considered in Johnson et al., (2006, p. 1733) to range from Pennsylvanian to early Triassic. The genus has a high ventral valve, very little inflated dorsal valve, wide hinge, and no tabellae, with other features, and so strongly differs from *Hartea*.

Hartea venustus n. gen., n. sp.

Fig. 41 - 50

Derivation: venustus – charming, Lat.

Diagnosis: Large elongate shells with fine median groove along each valve, dorsal valve gently convex, closely spaced ribs, especially on dorsal valve, micro-ornament of fine pustules. Slender lightly defined ventral adductor ridge, short tabellae.

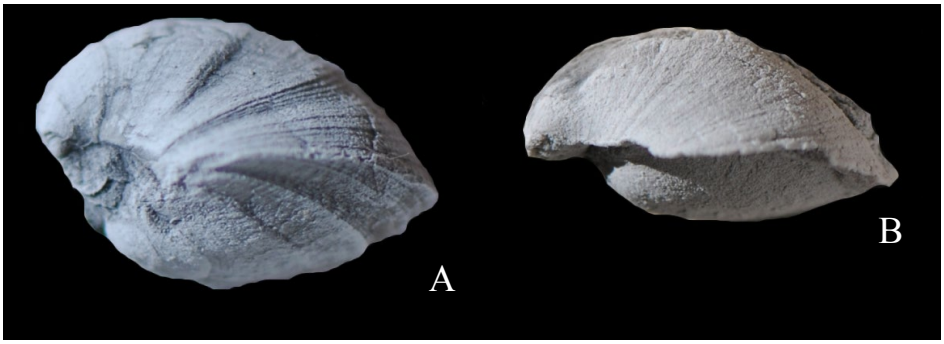


Fig. 43. *Hartea venustus* n. gen., n. sp. A, lateral aspect of specimen with valves conjoined, GSC 140256 from GSC 53743. See Fig. 45C, D. B, lateral aspect of specimen with valves conjoined, GSC 140257 from GSC 53744. See also Fig. 47C. Specimens x4, ventral valve on top.

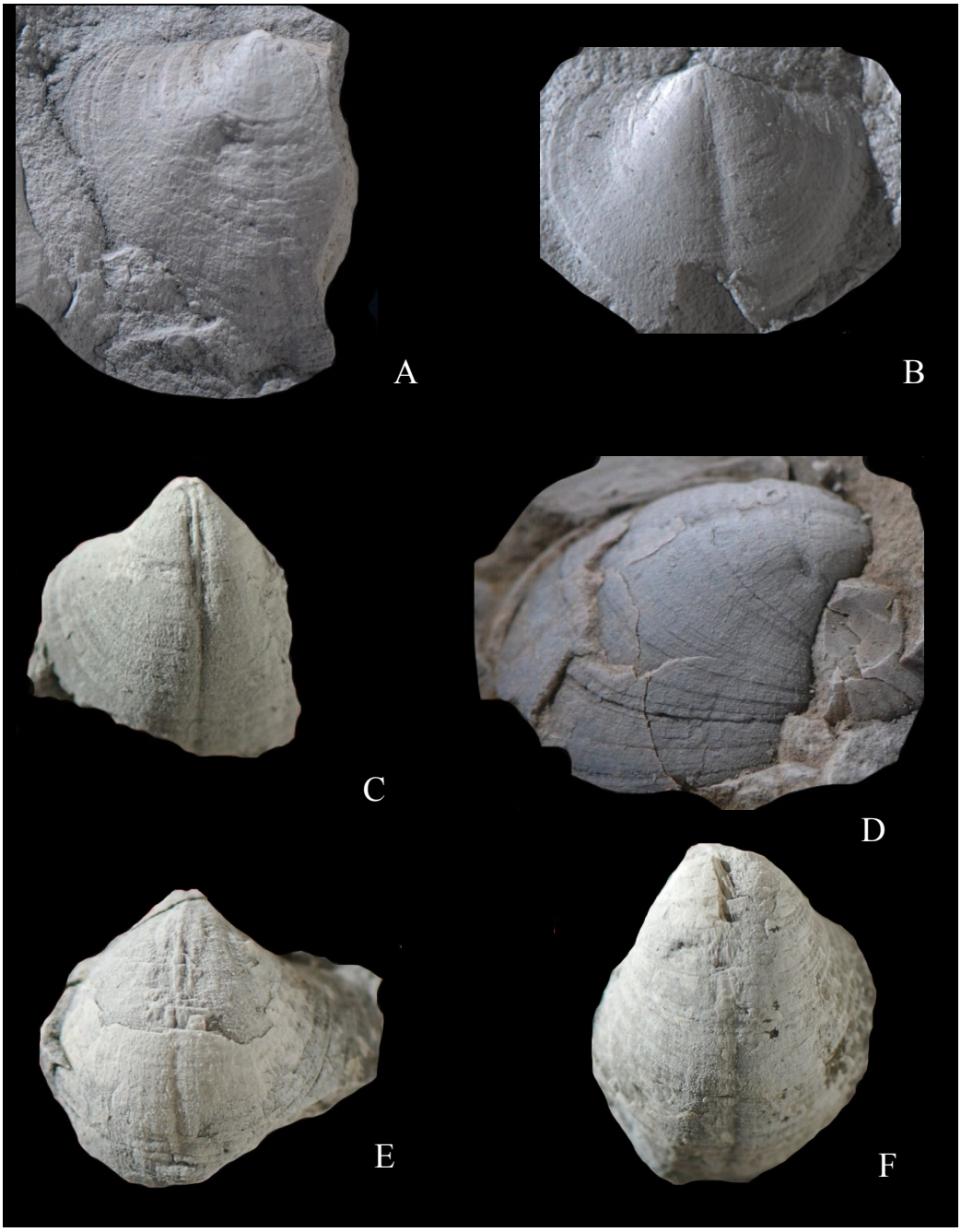


Fig. 44. *Hartea venustus* n. gen., n. sp. A, dorsal aspect of large but broken specimen with only a faint median groove, GSC 140271 from GSC 53749. B, dorsal valve GSC 140268 from GSC 53743. C, ventral valve GSC 140258 from GSC 53744. D, lateral aspect of ventral valve GSC 140259 from GSC 53749. E, ventral valve GSC 140260 from GSC 53745. F, dorsal valve GSC 140261 from GSC 53743. Specimens x4, except D x3.5.

Holotype: Specimen GSC 140254 illustrated in Fig. 42E, here designated.

Material: Single ventral valves from GSC 53740 and 53743, one dorsal valve from GSC 53742, nineteen ventral valves, four dorsal valves and five specimens with valves conjoined from GSC 53744, fifty one ventral valves, nineteen dorsal valves and twenty specimens with valves conjoined from GSC 53745, nine ventral valves, two dorsal valves and one specimen with valves conjoined from GSC 53748, and seventeen ventral valves, six dorsal valves and a specimen with valves conjoined from GSC 53749.

Dimensions in mm: both valves

Width	Length	Height	locality
10	11	7.3	53743
9	9	6	53745
11.4	10	6.2	53745
12.8	13.2	9	53745
14	13.8	6.5	53745
14.6	13	8	53744

Description: Some of the specimens are comparatively large for the family, a ventral valve from GSC 53743 measuring 16mm wide, 18mm long and 12mm high, and there are a number at comparable size. The ventral valve is much more inflated than the dorsal valve, which is approximately only half as high as the ventral valve, and both valves vary a little in dimensions and proportions. The ventral valve is subelongate as a rule with prominent and incurved umbo, varying in angle from 55^{o} to 85^{o}, though close to 70^{o} or 80^{o} as a rule, and high gently concave interarea. The posterior walls are high, and the hinge wide, with obtuse cardinal extremities. The ventral interarea is high and incurved, with delthyrium of angle up to 40^{o} to 50^{o}, possibly open, but covered by recalcitrant matrix. The dorsal valve is gently convex, with maximum width just in front of the hinge and swollen notothyrium. The nepionic portion is more convex and the interarea is very low. A shallow and narrow ventral groove commences at the ventral umbo, and a similar groove is developed over the dorsal valve, and in some specimens becomes slightly wider and deeper anteriorly. The surface of both valves is covered by fine pustules, some eight in 1mm anteriorly, without elongate bases. The pustules are arranged along commarginal rows numbering close to four in 1mm as a rule between small growth increments, and over larger, better spaced growth steps, which are especially pronounced on the dorsal valve. On some specimens, especially dorsal valves, there are fine radial ribs, numbering two in 1mm anteriorly, and these are enhanced when the outermost layer of shell is removed. This inner layer shows fine pits rather than pustules.

There are small teeth and a low dental flange along each side of the delthyrium. Adductor ridges, divided by a low ridge, arise in front the umbo and extend over the posterior two fifths of the shell length. They are not very high or wide, unlike those in a number of Permian allies (see Waterhouse 1964, 2016, 2018).

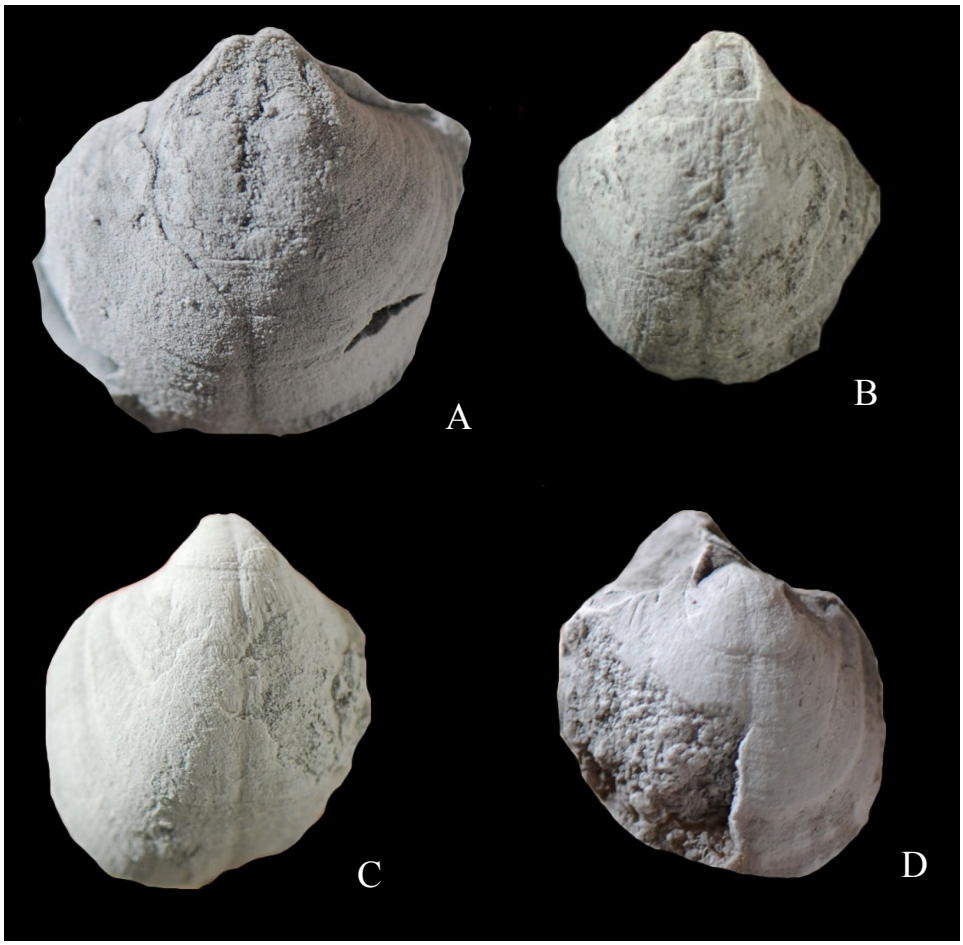


Fig. 45. *Hartea venustus* n. gen., n. sp. A, ventral valve GSC 140262 showing micro-ornament of pustules and growth increments. B, ventral valve GSC 140263. C, D, ventral and dorsal aspects of specimen with valves conjoined, GSC 140256. See Fig. 43A. Specimens x4 from GSC 53743.

The dorsal interior is not well exposed, and it has proved difficult to ascertain or confirm critical aspects of the dorsal interior. Two short tabellae diverge from the hinge, and a low median ridge extends over less than the posterior half of the shell. The cardinal process is small with four vertical lobes on the inner side. No adductor impressions are visible, though

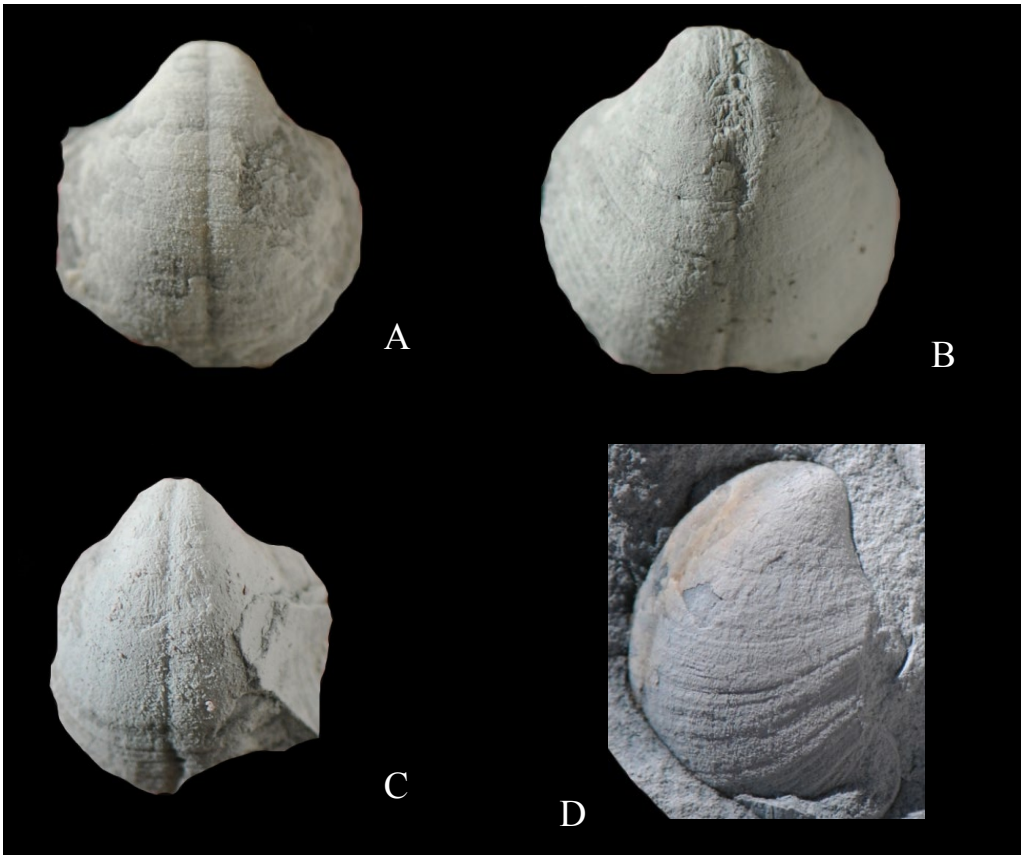


Fig. 46. *Hartea venustus* n. gen., n. sp. A, ventral valve GSC 140264 showing micro-ornament from GSC 53744. B, ventral valve GSC 140265 from GSC 53743. C, ventral aspect of specimen with valves conjoined, GSC 140252 from GSC 53744. (See also Fig. 42C). D, lateral aspect of ventral valve GSC 140266 from GSC 53749, with pustules preserved towards anterior margin, shown at base of figure. Specimens x4.

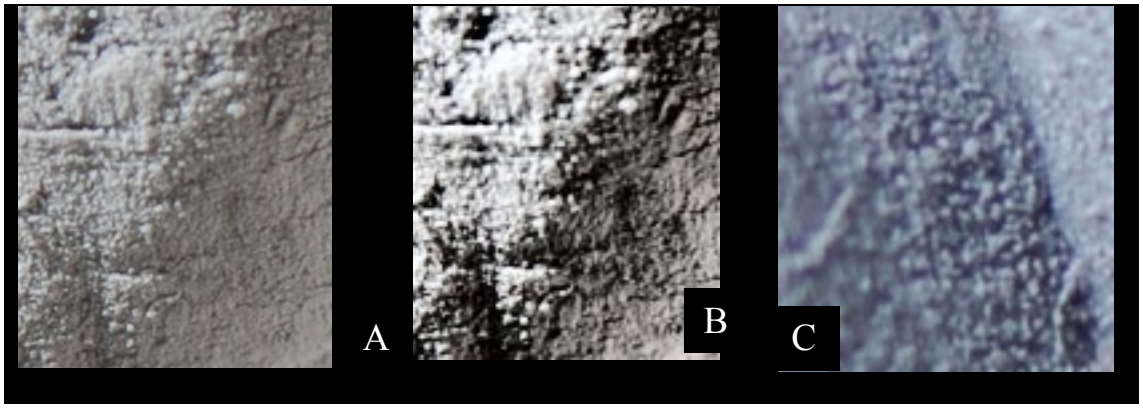


Fig. 47. *Hartea venustus* n. gen., n. sp. A, B, micro-ornament processed by regular and local equalization, ventral valve GSC 140264 from GSC 53744, x15. See Fig. 46A. C, micro-ornament in dorsal valve GSC 140257 from GSC 53744, x17. See Fig. 43B.

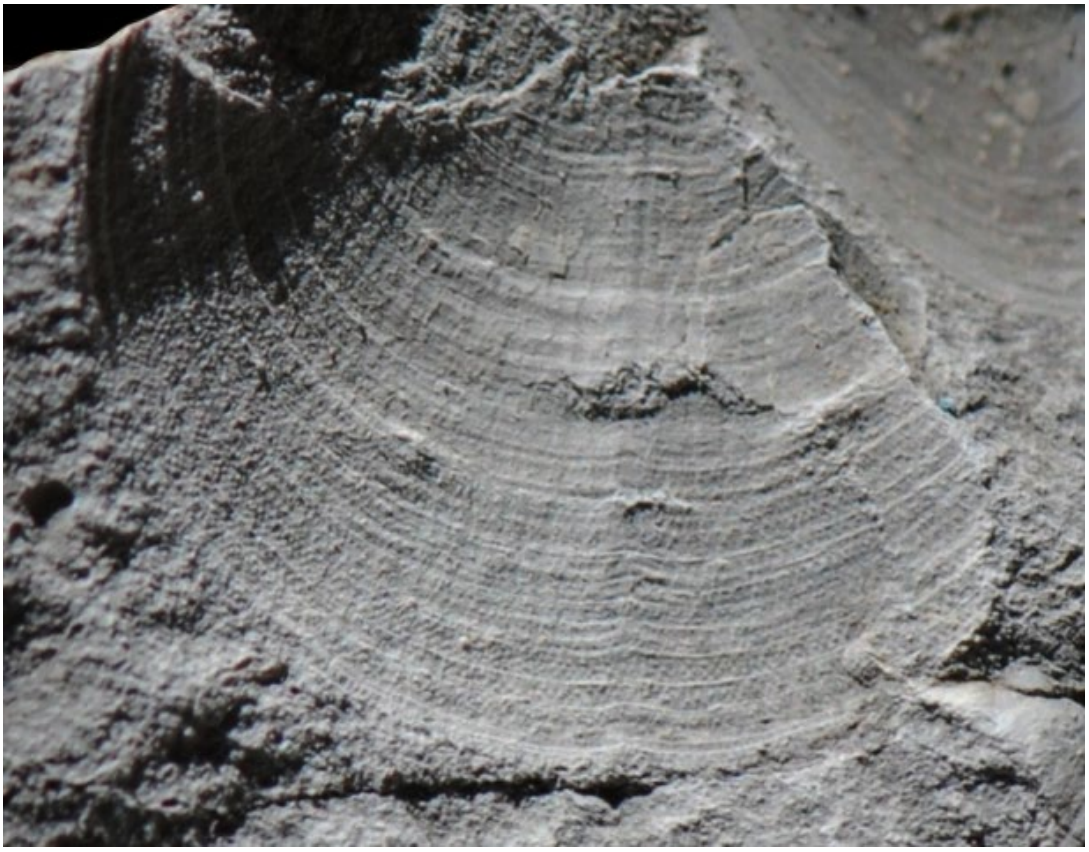


Fig. 48. *Hartea venustus* n. gen., n. sp., dorsal valve GSC 140267 showing micro-ornament of apparent pits and growth increments as well as very fine close-set ribs, from GSC 53749, x15. Other dorsal valves show that the pits lie below a thin outer layer of pustulose shell.

Fig. 49. *Hartea venustus* n. gen., n. sp., heavily leached interior of dorsal valve, GSC 140269 from GSC 53749, x7, showing remnants of silicified spiralia.

some specimens give the impression of a pair of faint oval scars in front of the tabellae. One specimen shows four well spaced coils of the spire (Fig. 49).

Resemblances: The specimens recorded as *Ambocoelia levicula* Rowley from the Moorefield Shale of Arkansas by Girty (1911, p. 73, pl. 8, fig. 7-9) have a less elongated ventral umbo, a more prominent ventral sulcus, and lack tabellae, though they suggest fine ribbing and are bisulcate. It is not certain therefore that they are congeneric.

Superorder TEREBRATULIFORMI Waagen, 1883

Order TERBRATULIDA Waagen, 1883

Superfamily **DIELASMOIDEA** Schuchert, 1913

Dielasmoid gen. & sp. indet. A

Fig. 50

Material: A ventral valve comes from GSC 53740 and another from GSC 53749.

Description: The internal moulds have a median ventral ridge, but the posterior is lost and the dorsal valve not known. A ventral valve was also recorded from GSC 53745 by Bamber & Waterhouse (1971, pl. 1, fig. 15), but this shows the external shell without a median groove.

Fig. 50. Dielasmoid gen. & sp. indet. A, partly decorticated ventral valve GSC 140270 from GSC 53740, x3.

Comparison with the initial survey by Bamber & Waterhouse (1971)

The Hart River brachiopods were briefly summarized in Bamber & Waterhouse (1971) from the lower part of the type section at Peel River (GSC loc. 53740-53746), and from the headwaters of Eagle River at section 116I-6 (Bamber 1972, pp. 115, 116). *Quadralosia* (then identified as *Quadratia*) predominated throughout the outcrops, and included a limited fauna with specimens of *Ovatia* and *Flexaria* in GSC 53738 and 53739. Taxa were reported as ?*Cancrinella* sp. from GSC 53760 (Bamber & Waterhouse 1971, pl. 1, fig. 7, 8) in section

116I-6 at Eagle River (Bamber 1972, p. 115), choristitid (Bamber & Waterhouse 1971, pl. 1, fig. 13, 16) from GSC 53739 at section 116H-1B, Peel River (Bamber 1972, p. 109) and *Neospirifer* (Bamber & Waterhouse 1971, pl. 1, fig. 11, 12) from GSC 53759, section 116I-6, Eagle River (Bamber 1972, p. 115). They are not available, but some allied specimens may be represented in the present suite, without it being possible to make direct comparison. The absence from available collections of shells like those called *Ovatia* is particularly to be regretted, and the illustrations for specimen GSC 26810 from GSC 53738 at section 116H-1B, Peel River (Bamber 1972, p. 109) certainly suggest *Ovatia* (Bamber & Waterhouse, pl. 1, fig. 18, 19). The genus was also reported from GSC 53922 in section 116J-4A near Cathedral Rocks (Bamber 1972, p. 124). Waterhouse (1968c, pp. 41-42) documented the occurrence of what is now called the *Quadralosia delicata* Zone at Cathedral Rocks in section 116J-4 at GSC localities 53911 to 53916; Palmer Lake (GSC 53750, 53752) and Eagle River West (GSC 53753-53757, 53759) and Eagle River East (53764, 53766). The fossils in the Hart River Formation exposed along the Peel River and Palmer Lake at section 4BR-62 were identified in a preliminary list in Waterhouse (1968d, p. 14).

CORRELATION

The age of the *Quadralosia delicata* Zone of the Hart River Formation is judged to be upper Visean. The best evidence for this age is offered by *Goniatites crenistria* (Phillips, 1836, p. 234, pl. 19, fig. 7-9) as identified by Sellers & Furnish (1960) from approximately 340ft above the base of the type section 116H-1B along the Peel River (Bamber & Waterhouse 1971, p. 51), reinforced by *G. granosus* Portlock (Mamet & Bamber 1979, p. 49). The ammonoids were deemed to point to an upper Visean age, equivalent to lower Chester of the Mississippi Valley. The species *crenistria* has also been reported from the Prophet Formation of northeastern British Columbia in Bamber et al. (1968, p. 7). Foraminifera found with *G. crenistria* have been assigned to Zone 16i or 16s of Late Visean or lower Chester age by Mamet in Bamber & Waterhouse (1971, p. 198), as set out by Mamet & Skipp (1970). Upper Visean conodonts were reported by C. M. Henderson in Bamber et al. (1989, p. 18) from Peel River outcrops, and Late Visean palynomorphs recorded from the upper Ford Lake Formation and all but the uppermost Hart River Formation in the south Eagle Plain. The palynomorph

Florinites of early Serpukhovian age was recorded from outcrops in the uppermost Hart River Formation (Bamber et al. 1989, p. 19). These assessments appear to be largely consistent with the age suggested by the modest assemblage of brachiopods described in this study, but the brachiopods do not in themselves clearly indicate whether they are of upper Visean or Serpukhovian age.

The most striking aspect of the brachiopod component is the overall similarity to aspects of the brachiopods from the Moorefield Shale of Arkansas, as described by Girty (1911). Various species are similar in general appearance (see Table 2), even though not exactly the same, including species of *Orbiculoidea, Flexaria, Quadralosia* which is a close ally of *Quadratia, Rhynchoporusia* and *Hartea*, a degree of similarity much greater than that between the Hart River Formation and the Etherington Formation of Alberta, as evaluated by Nelson (1961b), even though the Etherington faunas are much closer in terms of distance to those of the Yukon Territory. This similarity may be due to age, or to similarity in facies, or probably a mixture of both. On the face of available evidence, the Moorefield Shale is supposed to be basal Chester and upper Meramec (Sutherland & Manger, 1979, back cover), whereas the Foraminifera and ammonoids have been evaluated as lower Chester. The higher paleolatitudes and geographic separation from Arkansas of the Hart River species may help explain the differences between the two faunal assemblages, and the additional appearance of genera belonging to Retariidae and Yakovleviidae, and appear to reflect a more northerly influence, with possible input from the Arctic, including Russia, and quite possibly Alaska, for which the faunas remain very poorly known.

Of the brachiopod species, *Flexaria* is largely though not entirely limited to upper Visean and perhaps Serpukhovian faunas, and shown as ranging from Osagean through Meramecian and Chesterian into early Pennsylvanian by Carter (1990b, Fig. 2). The genus was recorded as *Buxtonia semicircularis* Sutton & Wagner, 1931 from the Kincaid Limestone in Kentucky, of upper Chesterian age (Swan, 1963, p. 47). Furthermore, Henry & Sutherland (1977, p. 109) reported a new species in the *Sandia welleri* Zone of Morrowan age in the Ozarks of Oklahoma. In writing chiefly of Spanish faunas, Winkler-Prins (1982, p. 62) considered that the genus lasted only till the end of the Visean (which may have included Serpukhovian). *Productus* (*Pustula*) *piscariae* Waterlot, 1932 from the Westphalian of

List of brachiopods from Moorefield Shale as named by Girty 1911	**Brachiopods from Hart River Formation** as described herein
Lingula batesville Girty	
L. albapinensis Walcott	
Lingulidiscina newberryi moorefieldiana Girty	
L. newberryi marshallensis Girty	
L. newberryi ovata Girty	*Orbiculoidea* sp.
L. newberryi caneyana Girty	
Chonetes sericeus Girty	
Chonetes sp.	
Productus inflatus coloradoensis Girty	***Praehorridonia*** sp..
P. arkansanus multiliratus Girty	***"Kutorginella" primigenius* n. sp.**
P. pileiformis Girty	***Marginirugus* sp.**
P. biseriatus Hall	*Flexaria echinata* n. sp.
P. subsulcatus Girty	**Magniplicatin gen. & sp. indet.**
P. subsulcatus janus Girty	***Calliprotonia* sp.**
P. moorefieldanus Girty	
P. moorefieldanus pusillus Girty	***Krotovia* sp.**
Productella hirsutiformis Walcott	*Quadralosia delicata* Waterhouse
P. hirsutiformis batesvillensis Girty	
Diaphragmus elegans Norwood & Pratten	***Muirwoodiciana* n. sp.**
Rhipidomella arkansana Girty	*Rhynchoporusia multiplicata* n. gen., n. sp.
Liorhynchus carboniferum Girty	
Liorhynchus carboniferum polypleurum Girty	
Camarotoechia purduei Girty	
C. purduei agrestis Girty	
C. purduei laxa Girty	
Moorefieldiella eurekensis Walcott	
M. eurekensis subcuboides Girty	
Harttina brevilobata Girty	Choristitid gen. & sp. indet.
Harttina brevilobata marginalis Girty	
Spirifer arkansanus Girty	
S. moorefieldanus Girty	Martiniin gen. & sp. indet.
S. increbescens Hall	
Reticularia setigera Hall	***Hartea venustus* n. gen., n. sp.**
Martinia glabra Martin?	
Martinia sp.	**Dielasmoid gen. & sp. indet.**
Ambocoelia levicula Rowley?	
Spiriferina subelliptica fayettevillensis Girty?	
Composita subquadrata lateralis Girty	
C. madisonensis pusilla Girty	
C. aff. *humilis* Girty?	
Eumetria marcyi Shumard	

Table 2. Summary of the large number of brachiopods listed from the study of Moorefield Formation in Girty (1911), and the Hart River brachiopods. Hart River brachiopods apparently absent from the Moorefield Shale are shown in bold, and those allied or similar are shown in regular font.

Belgium looks very close to being an exceptional species of *Flexaria* (see p. 17).

Marginirugus was shown as limited to Osagean, or lower Visean in ranges for brachiopod genera in the Mississippian Valley by Carter (1990b, p. 150; Brunton et al. 2000, p. 469), with a slightly younger range in New South Wales (Campbell, 1957). *Rhynchoporusia* is very close to possible members of the same genus in the Moorefield Shale. Several of the Hart River brachiopods, involving Martiniin gen. & sp .indet. and Choristitoid gen. & sp. indet. A are not known well enough to decipher their precise implications with regards to age.

Quadralosia delicata **Biozone**

It is proposed to refer the faunas from the Hart River Formation to the *Quadralosia delicata* biozone. This species, together with *Rhynchoporusia multiplicata* and *Hartea venustus*, are the most numerous of brachiopod species found in the formation, and together make up most of the biomass. Other characteristic species include *Flexaria echinata* and the distinctive *Muirwoodiciana* n. sp. The age is considered to be late Visean (Alekseev et al. 2004, Fig. 1; Heckel 2004, Fig. 1).

BRACHIOPODS FROM THE BLACKIE FORMATION AT PEEL RIVER

Buxtonia sulcata Zone

Lithology

The Blackie Formation has been collected intensively by the writer along the southern bank of the Peel River, opposite a reference section designated for Unit 2 in Bamber & Waterhouse (1971), and subsequently transferred to the Blackie Formation of Pugh (1983) by Bamber et al. (1989). Beds overlying the unit as restricted in Bamber & Waterhouse (1971) also belong to the formation, rather than Ettrain equivalents, as explained in 1971, p. 142. Fossils come mostly from fine-grained rocks, weathering orange-brown from black mudstone. The rock is extremely dense, suggesting the present of barite, though this is yet to be verified.

SYSTEMATIC DESCRIPTIONS

Phylum Brachiopoda Duméril, 1806

Subphylum Linguliformea Williams et al. 1996

Class Lingulata Gorjansky & Popov, 1985

Order LINGULIDA Waagen, 1885

Superfamily **DISCINOIDEA** Gray, 1840

Family **DISCINIDAE** Gray, 1840

Genus ***Orbiculoidea*** d' Orbigny, 1847

Orbiculoidea sp. B

Fig. 51

Fig. 51. *Orbiculoidea* sp. B, ventral valve GSC 140272, x3.

Material, Description: A single valve is available. The apex is more centrally placed than in *Orbiculoidea* sp. A from the underlying Hart River Formation.

Class Strophomenata Williams et al., 1996

Superorder STROPHOMENIFORMI Öpik, 1934

Order TRIPLESIIDA Moore, 1952

Suborder **ORTHOTETIDINA** Cooper & Grant, 1974

Superfamily **ORTHOTETOIDEA** Waagen, 1884

Family **SCHUCHERTELLIDAE** Williams, 1953

Subfamily **STREPTORHYCHINAE** Stehli, 1954

Diagnosis: Ventral interarea low to high with convex pseudodeltidium which is not folded into monticulus, perideltidium usually present, dorsal low interarea with chilidium, socket ridges and low median myophragm. Further comments about classification are provided on p. 147.

Streptorhynchin gen. & sp. indet. A

Fig. 52, 53

Material: A specimen with valves conjoined, and a larger ventral valve.

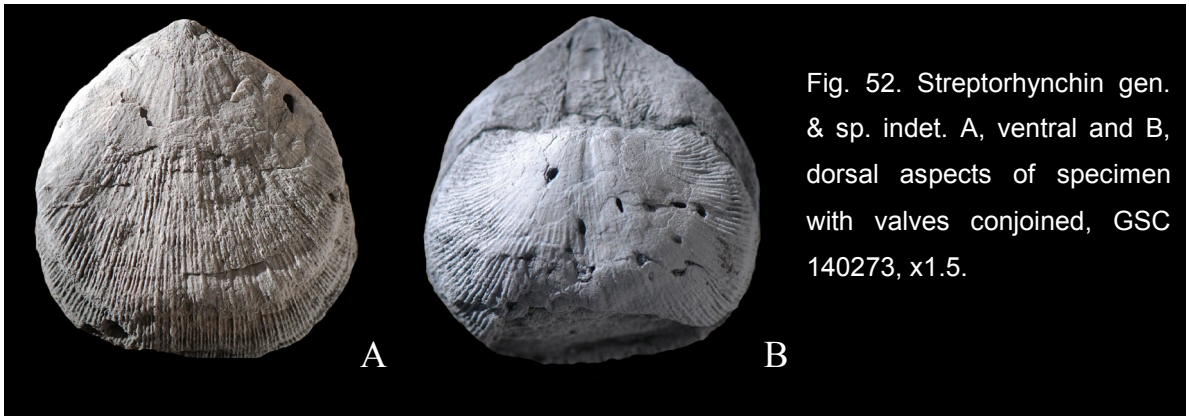


Fig. 52. Streptorhynchin gen. & sp. indet. A, ventral and B, dorsal aspects of specimen with valves conjoined, GSC 140273, x1.5.

Description: The specimen with valves conjoined measures 31mm wide, 33mm long and nearly 17mm high. The ventral valve in this specimen is less than 6mm high, as if it has been flattened,

and the dorsal valve is 13mm high. The ventral umbo is prominent, the interarea high with gently convex pseudodeltidium, no visible perideltidium perhaps because of wear, and the hinge wide. There is no median sulcus, but the swollen dorsal valve bears a shallow median channel. Costae are fine, nine to ten in 5mm at the anterior margin, with more prominent primary ribs, at least over the ventral valve. The inside face of the pseudodeltidium is gently convex, with narrow median groove over mid-length (Fig. 52B). The single ventral valve is larger, 36mm wide and long, and convex at 12mm high, with differentiated primary ribs.

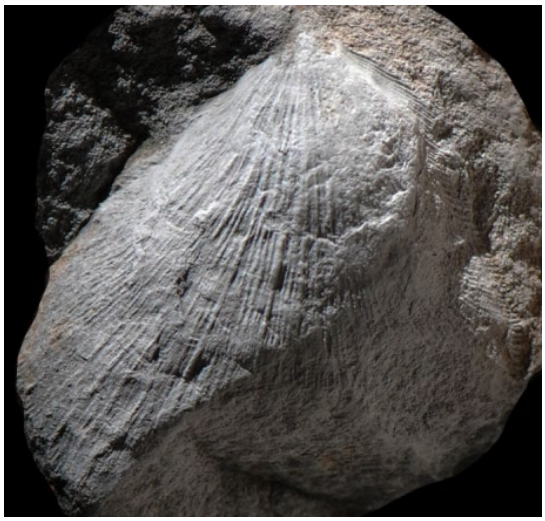


Fig. 53. Streptorhynchin gen. & sp. indet. A, ventral valve GSC 140274 x2.

Discussion: The interior of this taxon is not revealed, so that its identification is insecure. In size and relative dorsal/ventral inflation, it matches specimens of *Arctitreta* Whitfield, 1908, as described from the mid-Permian Assistance Formation of the Canadian Arctic, but the pseudodeltium in this genus does not have a corresponding low median groove towards the commissure.

Genus ***Kiangsiella*** Grabau, 1927

Diagnosis: Distinguished by strong plication as well as fine costellae, otherwise like *Streptorhynchus*.

Type species: *Orthotetes tingi* Grabau, 1924, p. 359, from basal Permian of Kiangsi, China, OD.

Kiangsiella sp.

Fig. 54

Material, Description: A fragment is available, possibly of a dorsal valve, becoming plicate anteriorly, with about twelve plicae. Fine posterior ribs numbering eight to nine in 5mm, increasing by branching and with the primary rib dominant.

Fig. 54. *Kiangsiella* sp., fragment showing posterior fine ribs and decorticated anterior plicae, GSC 140275 x3.

Superorder PRODUCTIFORMI Waagen, 1883

Order CHONETIDA Muir-Wood, 1955

Superfamily **CHONETOIDEA** Bronn, 1862

Chonetoid gen. & sp. indet.

Fig. 55

Material, Description: A poorly preserved ventral valve has ribs, shape and ventral interarea somewhat like that of chonetoids, and shows a very low median septum, but details are obscure.

Fig. 55. Chonetoid gen. & sp. indet., ventral internal mould GSC 140276 x3.

Order PRODUCTIDA Waagen, 1883

Suborder PRODUCTIDINA Waagen, 1883

Superfamily **OVERTONIOIDEA** Muir-Wood & Cooper, 1960

Family **OVERTONIIDAE** Muir-Wood & Cooper, 1960

Subfamily **OVERTONIINAE** Muir-Wood & Cooper, 1960

Genus ***Fimbrininia*** Waterhouse, 2013

Diagnosis: Subelongate shells with sturdy spines emerging from the crests of commarginal rugae over ventral valve. Dorsal ornament of prominent dimples in quincunx, as well as numerous spines.

Type species: *Fimbrininia spinosa* Waterhouse, 2013, p. 52 from Jungle Creek Formation (Asselian), Yukon Territory, OD.

Discussion: *Fimbrinia* Cooper, 1972 is very close, but the ventral spines lie over the posterior slope of the commarginal rugae, whereas they emerge from the crest of the rugae in *Fimbrininia.*

Fimbrininia? sp.

Fig. 56

Material: Five worn ventral valves with additional fragments.

Fig. 56. *Fimbrininia*? sp., a cluster of ventral valves on slab 140277, x2.

Description. The specimens are much like those described from the Jungle Creek Formation by Waterhouse (2018), and have prominent spine bases emerging from the crest of prominent commarginal rugae. But dorsal ornament is not known.

Resemblances: *Fimbrininia*? *gracilis* (Abramov & Grigorieva, 1983, pl. 3, fig. 10-14) from the Middle Carboniferous upper Abaginsk Horizon of west Verchoyan is more transverse. Specimens closer in shape were described as *Fimbriaria gijigensis* Zavodowsky (1970, p. 91, pl. 35, fig. 1-3), reinforced by Abramov & Grigorieva (1983, p. 71, pl. 3, fig. 15-17) from the lower Kigiltass horizon, and this species is a little younger, of Upper Carboniferous age. *Fimbrinia*? *borealis* Carter & Poletaev, 1998 from the Hare Fiord Formation of Ellesmere Island comes closer in age at Atokan. Its ventral spines emerge from the crests of rugae as in *Fimbrininia*, but the species lacks dorsal spines and is referred to a separate genus, *Fimbrinusia* Waterhouse, 2013, p. 54. Present material lacks dorsal valves and so cannot be identified with confidence.

Family **AVONIIDAE** Sarytcheva, 1960

Subfamily **SEMICOSTELLINAE** Nalivkin, 1979

Genus ***Tuberculatella*** Waterhouse, 1982

Diagnosis: Ventral well spaced often elongate tubercles each bearing a spine, dorsal tubercles and dimples prominent. See Waterhouse 2018, p. 59.

Type species: *Tuberculatella bunnakia* Waterhouse, 2018 nom. nov, from Upper Carboniferous of northeast Thailand.

Tuberculatella? sp.

Fig. 57

Material: A single incomplete dorsal valve.

Description: The broken external mould of a dorsal valve suggests possible identity with *Tuberculatella*, given its shape, gentle concavity, fine commarginal growth increments, and moderately large well spaced dimples, but material is so incomplete that identification is no more than provisional, and in need of confirmation.

Fig. 57. *Tuberculatella*? sp., dorsal external mould GSC 140278, x3.

Superfamily **HORRIDONIOIDEA** Muir-Wood & Cooper, 1960

Family **HORRIDONIIDAE** Muir-Wood & Cooper, 1960

Subfamily **BAILLIENINAE** Waterhouse, 2013

Diagnosis: Ventral spines moderately numerous over valve, dorsal valve bearing spines over anterior valve and trail, no row of dorsal hinge spines. Costae moderately well developed, on either ventral or dorsal valve, or both. Hinge and ear spines not strongly specialized on either valve.

Discussion: The subfamily is characterized by the lack of a dorsal hinge row of spines, presence of numerous subequal ventral spines and common presence of well developed costae. It involves the genera *Bailliena* Nelson & Johnson and *Praehorridonia* Ustritsky. The presence of numerous spines on both valves, without a dorsal hinge row and the common presence of well ordered costae, provides a ready distinction from members of Horridoniinae Muir-Wood & Cooper and Sowerbininae Lazarev.

Genus ***Bailliena*** Nelson & Johnson, 1968

Diagnosis: Well inflated subequilateral to subelongate shells, ventral valve covered by prominent spine bases, including hinge row, dorsal valve with spines and pits over anterior disc and trail, no dorsal hinge row of spines. Spines seldom very broad for the size of the shell, but ventral spine bases may be strong; costae may be developed anteriorly.

Type species: *Bailliena yukonensis* Nelson & Johnson, 1968 from Ettrain equivalents (Kasimovian?) at Peel River, Yukon Territory, Canada, OD.

Bailliena nudymensis Sarytcheva, 1977a

Fig. 58

1970 *Pustula* ex. gr. *rugata* Abramov, p. 116, pl. 8, fig. 8.
1970 *Pustula* sp. Abramov, p. 117, pl. 8, fig. 9.
1977 *Bailliena nudymensis* Sarytcheva, p. 116, pl. 16, fig. 6, 7, pl. 17, fig. 1-3, Fig. 69, 70.
1983 *B. nudymensis* – Abramov & Grigorieva, p. 85, pl. 7, fig. 1, 2.

Diagnosis: Large weakly transverse to elongate shells distinguished by strong ventral spine bases.

Holotype: PIN no. 2833/150, figured by Sarytcheva (1977a, pl. 17, fig. 2) from Magar subhorizon, South Verchoyan.

Material: A specimen with valves conjoined, a ventral valve and part of a dorsal valve.

Description: The conjoined specimen is 59mm wide, 63mm long, and 34mm high. The ventral umbo is incurved, with angle of 85°, extending over moderately wide hinge with convex ventral ears, and cardinal angle close to 100°. Maximum width lies well forward towards the anterior third of the shell length. A well defined ventral sulcus commences a little in front of the sulcus and widens at 27°, with moderately deep and slightly angular floor. The dorsal valve is only gently concave, and is largely hidden in matrix. Spines cover the entire ventral valve, with slightly elongate bases over the umbonal region, and with strong elongate bases anteriorly, the spines erect and arising near mid-length of each base. The bases tend to be radially aligned, and are slightly larger in the separate ventral valve than in the conjoined specimen. Spines possibly form a row along the ventral hinge, and are not strong, and cluster over the inner ears as erect and fine spines. The incomplete dorsal valve shows part of the hinge, and this demonstrates the absence of a hinge row of spines, as in *Bailliena* Nelson & Johnson, as well as a little of the interior, including narrow median septum and weakly defined adductor scars.

Resemblances: The trail may have been lost, and information is sparse about the dorsal spines, though there do not appear to be any along the hinge. The best preserved of present specimens is more elongate than most specimens assigned to the species described as *Bailliena nudymiensis* Sarytcheva (1977a) from the lower Middle Carboniferous Magar subhorizon in

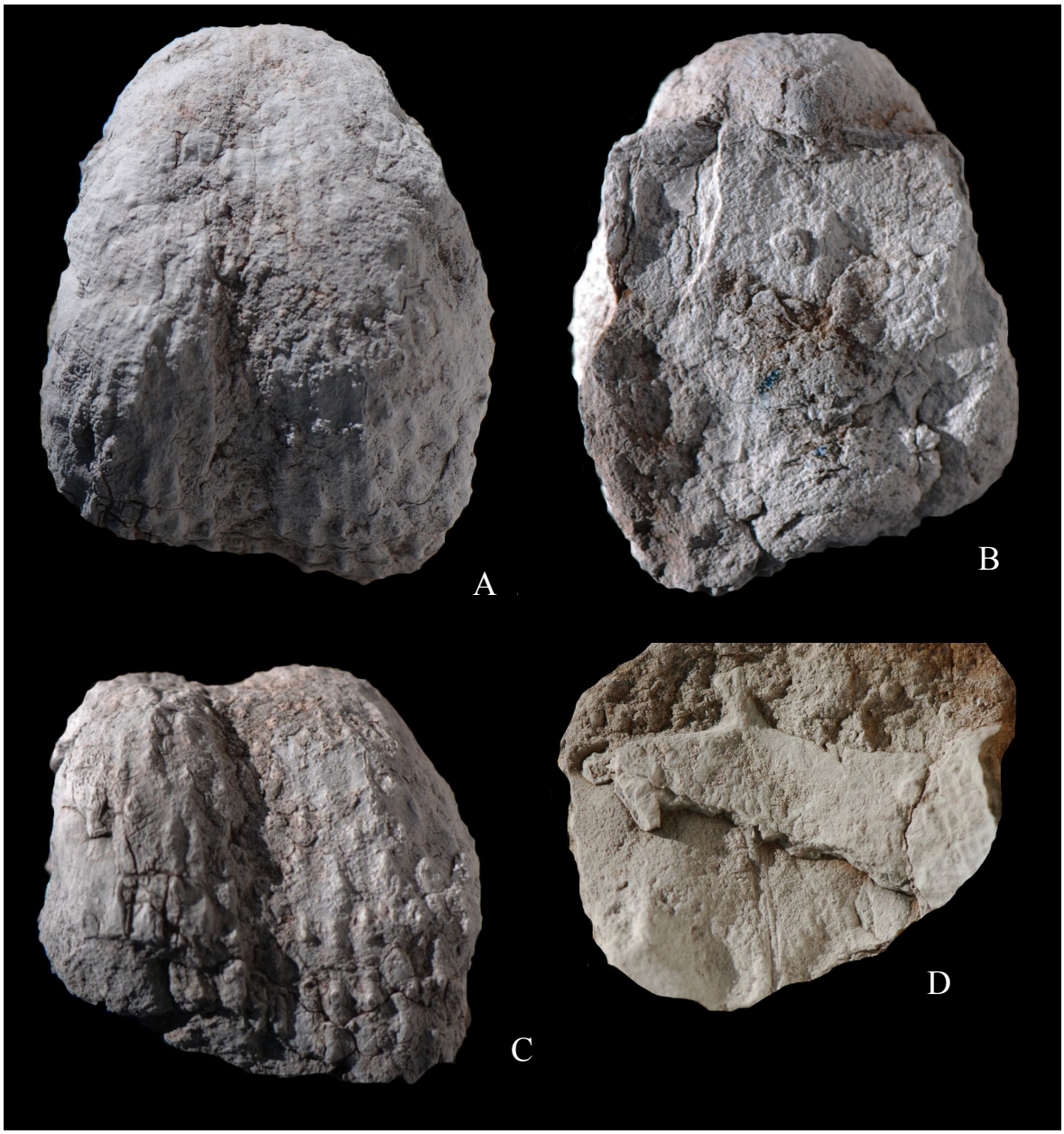


Fig. 58. *Bailliena nudymensis* Sarytcheva. A-C, ventral, dorsal and anterior ventral aspects of specimen with valves conjoined, GSC 140279 x1.5. D, broken posterior dorsal valve GSC 140280, showing absence of hinge row of spines, x2.

Kolyma-Omolonsk Massif which are closer to the unfigured and more transverse specimen. All individuals agree in displaying numerous and strong ventral spine bases. The species ranges from very late Mississippian into early Pennsylvanian, and has been reported from the Kolyma-

Omolon Massif, South Verchoyan and Taimyr. Lower Carboniferous material recorded as *B. nudymiensis* from south Verchoyan by Abramov & Grigorieva (1983, pl. 7, fig. 1, 2) includes an elongate specimen, with similar strong spine bases. *Praehorridonia* Ustritsky, 1962, first described from the lower Bashkirian of Taimyr in Arctic Russia, has more dorsal spines and fewer finer ventral disc spines, with other more minor differences, as illustrated in Sarytcheva (1977a) and evaluated in Waterhouse (2013, p. 88).

Superfamily **MARGINIFEROIDEA** Stehli, 1954

Family **COSTISPINIFERIDAE** Muir-Wood & Cooper, 1960

Subfamily **COSTISPINIFERINAE** Muir-Wood & Cooper, 1960

Tribe **ONOPORDUMARIINI** Waterhouse, 2013

Genus ***Onopordumaria*** Waterhouse, 1971

Diagnosis: Ovally elongate shells, ventral valve convex, dorsal valve flatly concave, spines arranged in quincunx or rarely in commarginal rows over both valves, arising from small tubercles, crowded and fine over ears. Shallow ventral sulcus, low dorsal fold. Ventral adductors non-dendritic, divided by myophragm, diductors slightly impressed, anterior trail rimmed by two or

Fig. 59. *Onopordumaria punctura* Waterhouse. A, ventral valve GSC 140281. B, ventral valve GSC 140282. Specimens x3.

three low growth ridges. Dorsal valve with cardinal process, low median septum, smooth adductor scars, few rows of large anterior pustules. Well defined marginal ridge or ridges in each valve.

Discussion: The relationship to other comparatively similar genera is discussed in Waterhouse (2013, pp. 104-106). The genus was placed by Brunton et al. (2000, p. 453) in Levipustulinae Lazarev, 1985, but *Levipustula* differs considerably, being characterized by its recurved spines with spine tunnels through the shell and having dorsal buttress plates. This genus lacks the high internal marginal ridges found in *Onopordumaria*, as shown in detail in an analysis of *Levipustula* in Canada and in other occurrences, including the type species, from eastern Australia (see p. 98), as well as allied material from Russia and Argentina.

Onopordumaria punctura Waterhouse, 1971

Fig. 59, 60

1971 *Onopordumaria punctura* Waterhouse, p. 205, pl. 23, fig. 12-17.
2000 O. *punctura* – Brunton et al., p. 453, Fig. 301a-c.

Material: Seven ventral valves and six dorsal valves with fragments belong to this species.

Description: The material has been described in Waterhouse (1971).

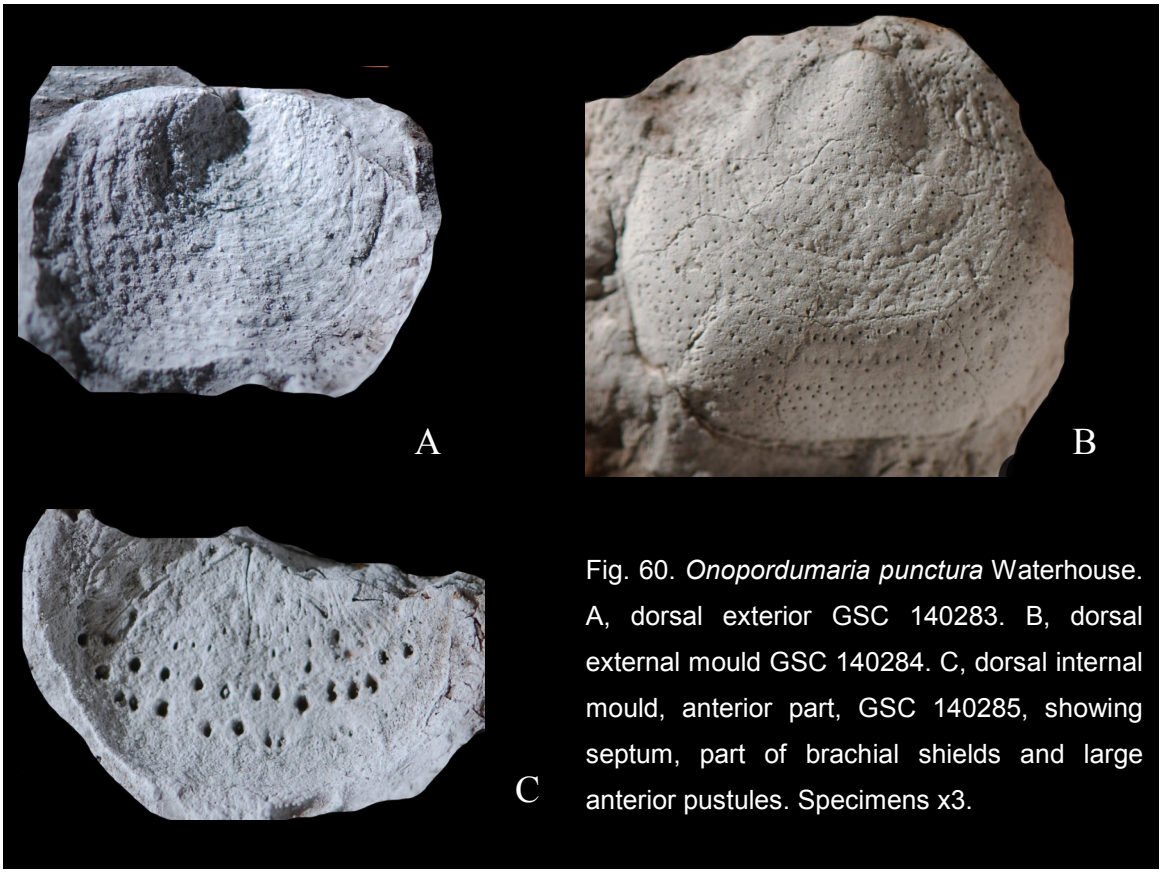


Fig. 60. *Onopordumaria punctura* Waterhouse. A, dorsal exterior GSC 140283. B, dorsal external mould GSC 140284. C, dorsal internal mould, anterior part, GSC 140285, showing septum, part of brachial shields and large anterior pustules. Specimens x3.

Superfamily **PRODUCTOIDEA** Gray, 1840

Family **BUXTONIIDAE** Muir-Wood & Cooper, 1960

Subfamily **BUXTONIINAE** Muir-Wood & Cooper, 1960

Genus ***Buxtonia*** Thomas, 1914

Diagnosis: Medium to large, ventral ribs fine, spines with elongate bases posteriorly and numerous fine spines anteriorly, erect dorsal spines, commarginal fine rugae especially over dorsal valve.

Type species: *Productus scabriculus* Sowerby, 1814 from Visean of England, SD ICZN 1956 Opinion 420, p. 143.

Discussion: Species assigned to *Buxtonia* vary somewhat in details of ornament, and the limits of the genus may need to be extended, or the group subdivided. *Setigerites* Girty, 1939, replacement name for *Setigerella* Girty, is very close to *Buxtonia*, apart from having fine and denser radial ornament and longer ventral disc spine bases in the type species. Comparisons offered with other genera by Muir-Wood & Cooper (1960) seem irrelevant to the genera concerned, whereas Brunton et al. (2000, p. 501) realized the close relationship between the two, although they offered no means of distinction.

Buxtonia sulcata n. sp.

Fig. 61 - 64

?1961a *Buxtonia setigerus* [not Hall] – Nelson, pl. 1, fig. 3a, b.
1971 *Buxtonia* sp. Bamber & Waterhouse, p. 122, pl. 3, fig. 10, 11, 13.

Derivation: sulcus – furrow, Lat.

Diagnosis: Large for genus, numerous spines over both valves, fine ribs and well formed ventral sulcus.

Holotype: Specimen GSC 140287, illustrated in Fig. 61B, C, here designated.

Material: Twenty nine ventral valves, sixteen dorsal valves and seventeen specimens with valves conjoined. Some of these specimens were also figured in Bamber & Waterhouse (1971).

Dimensions in mm:

Width	Length	Height
55	65	46 (both valves)
65	61	42 (ventral valve)
44	51	31 (both valves)
64	61	43 (both valves)

Description: Specimens are large, somewhat distorted, and generally incomplete, some without ears and others without trails or with incomplete ears and/or trails. A number tend to be narrow and

elongate, compared with others that are broader. The ventral umbo is incurved with an angle of 80° to 90° as a rule, and posterior walls diverge at this angle, steep and high, persisting to the maximum width which lies well forward. Beyond the posterior walls, the ears are small but distinct, gently convex, and jutting out with a rounded cardinal angle close to 70° or 80°. In front of the ears the lateral margins continue to diverge. A well formed ventral sulcus commences from 10 to 20mm in front of the umbo, and widens at an angle of 20°, continuing to widen as far as the anterior margin in some specimens, whereas in most the sulcal flanks tend to become parallel close to the anterior margin. The trail is long, and curves evenly on from the disc. The nepionic shell is small and convex, up to 7mm wide, but distinct in only some specimens. The dorsal valve largely mirrors that of the ventral valve, with concave nepionic shell, and over the disc is of only gentle concavity, so that the corpus of the shell is thick, and the trail curves evenly from the disc, without being geniculate. Dorsal ears are well formed, concave and of small to moderate size, and the fold is low and commences over mid-disc or further forward and becomes better developed though low and broad over the trail.

Both valves are covered by low round-crested costae, numbering four in 5mm near mid-length, five in 5mm anteriorly, and as fine as six in 5mm near the anterior margin of large specimens. At least some ribs increase by branching. Ears lack costae. On the dorsal valve, disc ribs are fine, up to six in 5mm at mid-disc, finer posteriorly, and slightly coarser in front, though the density varies somewhat, four in 5mm in some specimens, more in others. A few ribs are intercalated, but most increase by branching, a few even increasing from one to three. Low commarginal rugae cover the ventral disc, four in 10mm posteriorly, becoming five in 10mm anteriorly, and fading over the disc. The rugae cross the ears. Over the dorsal disc, the commarginal rugae are much more closely spaced, as many as fourteen in 10mm over the posterior mid-disc, and ten in 10mm over the anterior disc, and well spaced rugae continue over the disc. Small erect spines are dense over both valves. On the ventral valve, they cluster over the ears, without being thick, and there is a row close to the hinge, not outstanding because further spines lie just in front. The spines emerge from the crest of the ribs, without effecting much change to the rib profile. The spines are dense, and emerge in no discernibly quincunxial pattern. Dorsal spines are also dense, continuing to the anterior trail. A hinge row, poorly separated from anterior spines, is developed, and there are scattered ear spines. Spines become particularly dense over the anterior trail, especially over the lateral flanks, with five in 5mm along a row, and the suggestion in some specimens of bands, possibly related to growth rugae.

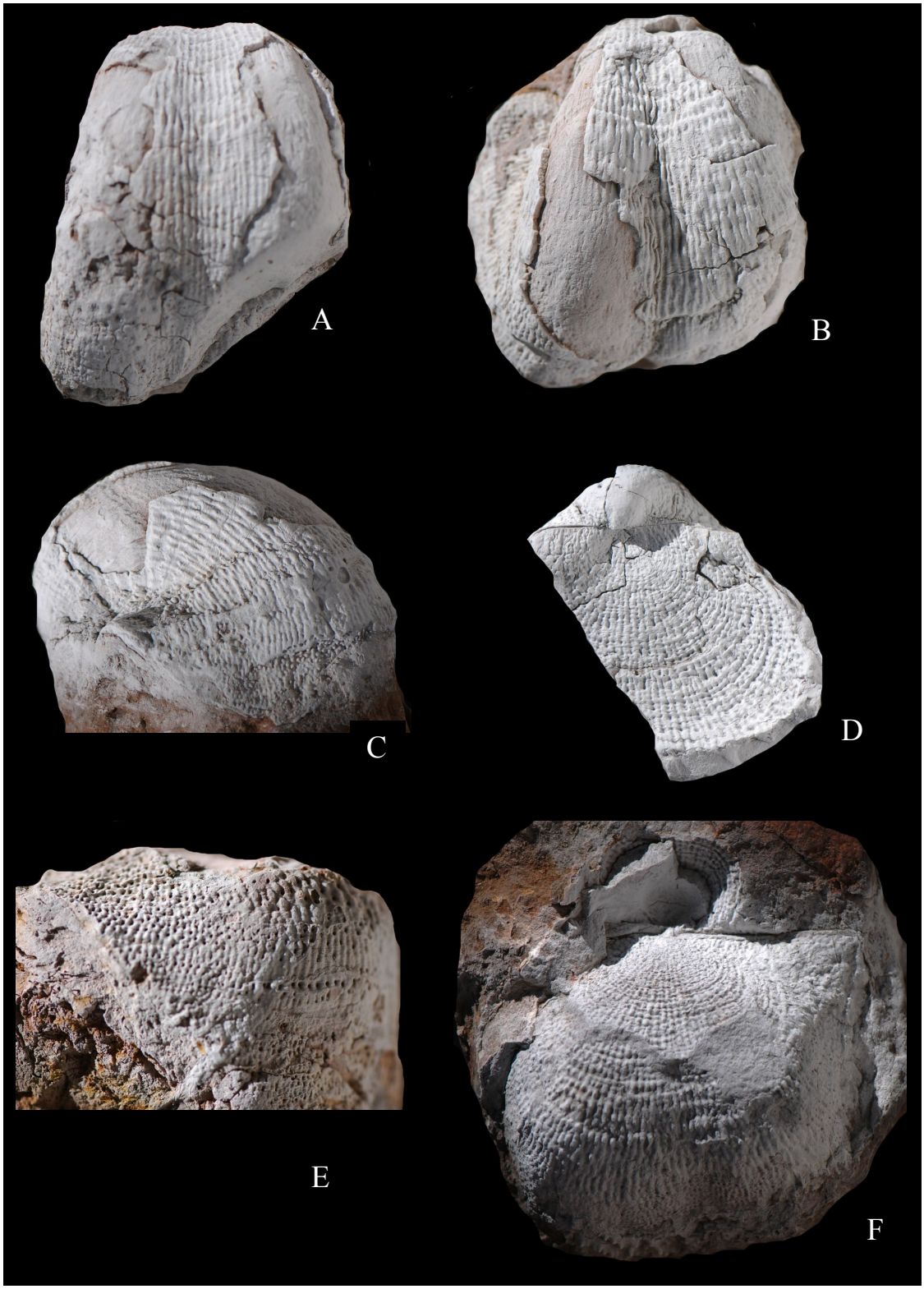


Fig. 61. *Buxtonia sulcata* n. sp. A, ventral valve GSC 140286. B, C, ventral and lateral aspect of specimen with valves conjoined, holotype GSC 140287. D, dorsal view of specimen GSC 140288. E, lateral view of external mould of dorsal valve, GSC 140289. F, dorsal view of chiefly dorsal external mould with part of ventral valve, GSC 140290. Specimens x1.

Fig. 62. *Buxtonia sulcata* n. sp. A, Dorsal external mould with part of ventral valve, GSC 140291 x1.5. B, dorsal aspect of specimen with valves conjoined, GSC 140292 x1. See also Fig. 63B.

Ventral adductor scars lie on a large elongate raised area divided by a broad groove. In a late mature specimen, a narrow ridge lies along the middle of the groove, and the adductor surface becomes marked by dendritic ridges and grooves. The diductor scars are oval, large and lying alongside the anterior adductors, and scored by longitudinal ridges and grooves. The posterior floor is comparatively smooth, and much of the anterior floor bears short elongate dimples and ridges.

In the dorsal valve a ridge lies along the hinge. The cardinal process is of moderate size, lying in the plane of the commissure, with three terminal lobes, the lateral two splayed apart, the median lobe subdivided by a groove over the inner face, and the process passes anteriorly into a narrower median septum, which in some specimens bears a median groove. The median septum extends for virtually the full length of the visceral disc, and may end in a small terminal pillar. The adductor scars lie to each side, involving a large pair marked by low dendritic ridges, and an anterior smaller more raised and smooth pair. There is no ridge across the inner ears, and no specimen shows brachial shields or enclosing ridges, even though preservation is good. The posterior floor has only subdued pustules and pits. Large pustules are developed over the trail, becoming as few as four in 10mm over the posterior trail in front of the first formed part, and then becoming finer in front, arranged in commarginal rows, with some irregularities.

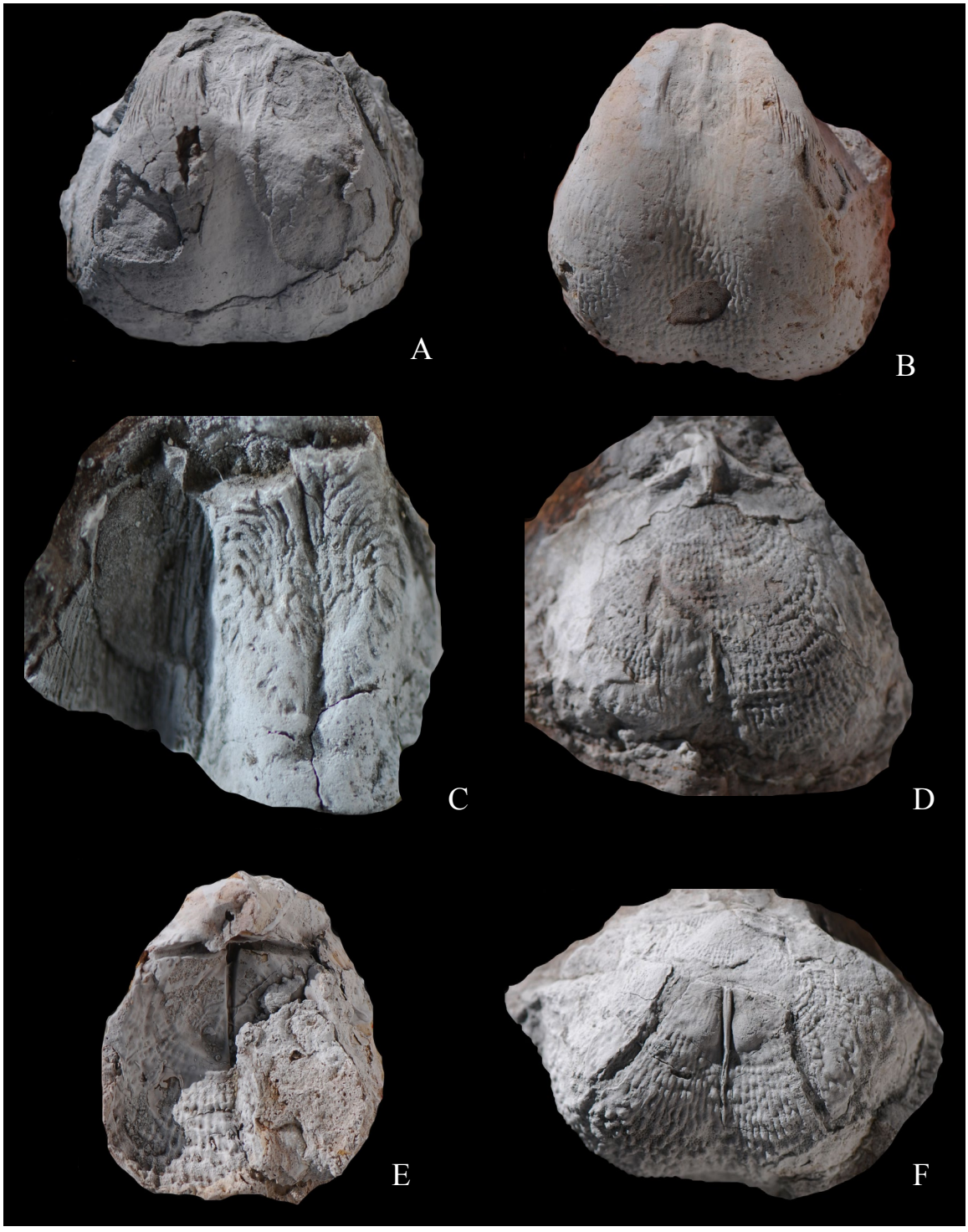


Fig. 63. *Buxtonia sulcata* n. sp. A, ventral internal mould of specimen GSC 140293 with valves conjoined. B, ventral view of internal mould GSC 140292. C, ventral muscle imprints, GSC 140294 x3. D, dorsal valve GSC 140295, interior preserved posteriorly, external mould mostly in front. E, dorsal aspect of internal mould, GSC 140296. F, dorsal valve GSC 140297, with anterior shell preserved, and exterior mould preserved posteriorly. Specimens x0.8, except Fig. 63C x3.

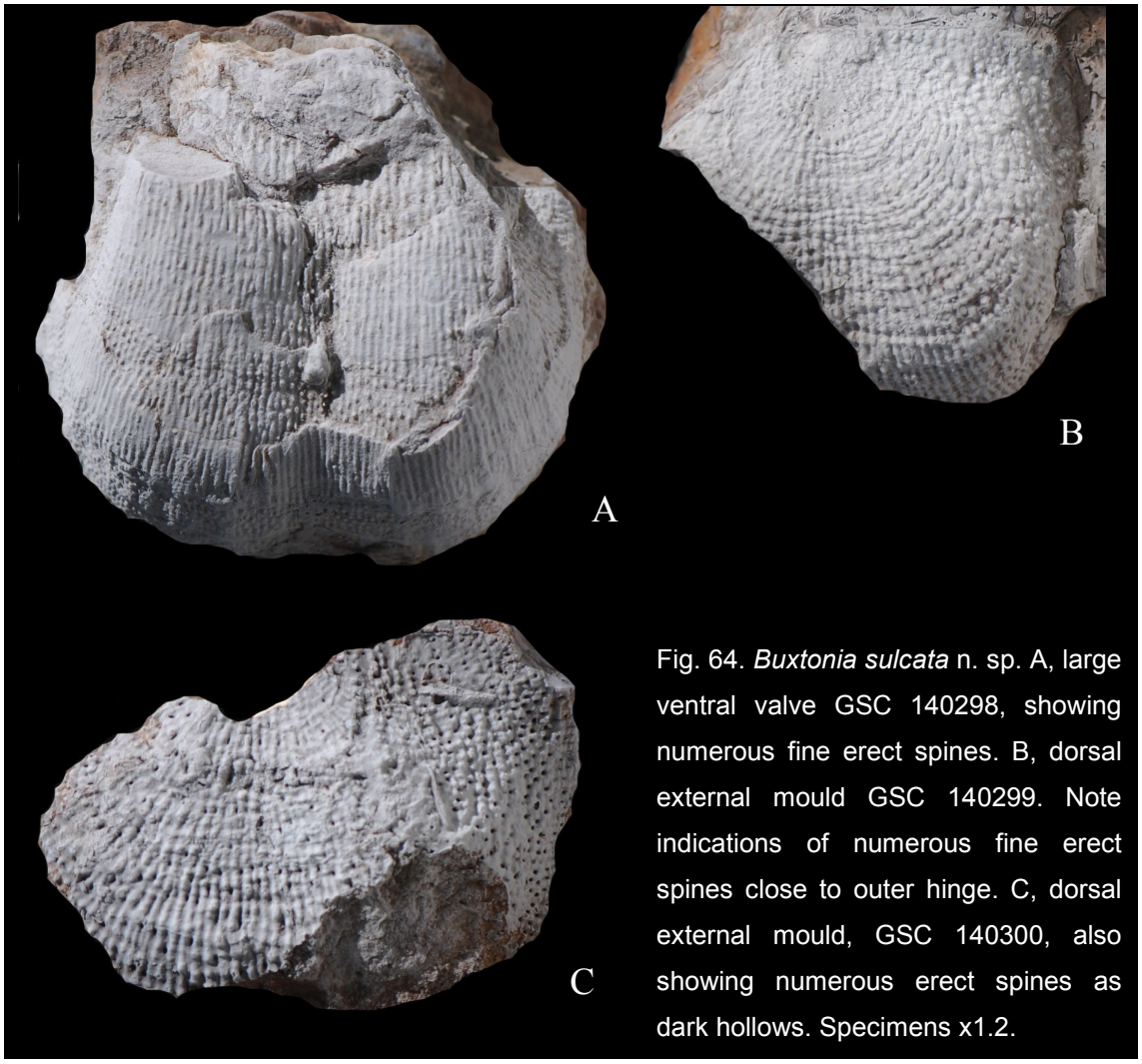


Fig. 64. *Buxtonia sulcata* n. sp. A, large ventral valve GSC 140298, showing numerous fine erect spines. B, dorsal external mould GSC 140299. Note indications of numerous fine erect spines close to outer hinge. C, dorsal external mould, GSC 140300, also showing numerous erect spines as dark hollows. Specimens x1.2.

Resemblances: Possibly *Buxtonia setigerus* (Hall) [= the type species of *Setigerites*] as recorded in a drawing by Nelson (1961a, pl. 1, fig. 3a, b) from what was supposed to be Calico Bluff beds in the Yukon Territory belongs to this species. The Calico Bluff beds of Alaska are of limestone and fossiliferous shale, unlike the Yukon beds (Bamber in Bamber & Waterhouse 1971, p. 50), which seem likely to belong to the Blackie Formation. The type species *Buxtonia scabricula* Sowerby, as figured by Sowerby (1814), Thomas (1914), Paeckelmann (1931), Muir-Wood (1928) and Muir-Wood & Cooper (1960), is smaller than the present form, with shallower sulcus and slight differences in the ornament, possibly in part due to slight wear of the English material. Donets specimens assigned to the species by Rotai (1951, pl. 3, fig. 1, 2) have stronger ribbing, like the Russian material assigned to the species in Sarytcheva & Sokolskaya (1952) and Sarytcheva (1960, pl. 36, fig. 1, 2), and a

Kun Lun specimen has stronger ventral spines base (Ustritsky 1960, pl. 5, fig. 5a, b). Ukrainian material of lower Visean age that was assigned to the species by Aisenberg (1962, p. 103, pl. 3, fig. 15, 16) has rather prominent spine bases.

Specimens of *Buxtonia* sp. illustrated by Muir-Wood & Cooper (1960, pl. 74, fig. 1-6) from the Fayetteville Shale of Oklahoma are more transverse, small, and again without well defined ventral sulcus. Ventral spines are more conspicuous on this form.

Buxtonia scabriculoides Paeckelmann (see 1931, pl. 18, fig. 12a, b, 13) from Germany as illustrated by dorsal valves is small with apparently low trail. Visean specimens assigned to *scabriculoides* Paeckelmann from northeast Russia by Abramov (1965, p. 40, pl. 4, fig. 1, 2; 1970, pl. 10, fig. 8, pl. 11, fig. 1, 2) are large with moderately defined sulcus and rather strong ribs. *Buxtonia subscabricula* Aisenberg in Aisenberg et al. (1983, p. 80, pl. 38, fig. 9a, b, 10, 11) from the upper Serpukhovian of the Donets Basin is smaller with more gentle sulcus. The ventral spine bases are differentiated in fig. 10, and look more like those of *Juresania* rather than *Buxtonia. B. scabra* Aisenberg in Aisenberg et al. (1983, p. 81, pl. 39, fig. 1, 2) from the same beds has differentiated ventral spine bases in commargons, and *B. bankovskyi* Aisenberg in Aisenberg et al., 1983 seems somewhat similar, whereas *B. kumpani* Rotai (1939, p. 470; Aisenberg in Aisenberg et al. 1983, p. 138) is closer but has longer spine bases and less prominent ventral sulcus. Specimens ascribed to *scabricula* by Kalashnikov (1974, pl. 12, fig. 3, 4) also have long spine bases.

Kazakhstan specimens of lower Middle Carboniferous age (Bashkirian) that were assigned to *Buxtonia kalitvaensis* Licharew (1938, p. 78, pl. 2, fig. 3, 4; 1939, p. 87, pl. 18, fig. 4, 5) and in Sarytcheva (1968, p. 115, pl. 12, fig. 1-6) have prominent commarginal bands with somewhat subdued radial fila. The size is large, but the sulcus shallow. Further references include reports from Donbass, the Urals, Fergana and even Lower Permian of Darvas. A large specimen ascribed to *B. kalitvaensis* Licharew by Volgin (1960, p. 55, pl. 4, fig. 1) of Upper Carboniferous age from south Fergana has well defined commarginal rugae, and similar rugae are developed in the smaller specimens identified with *B. mosquensis* Ivanov (1935, p. 25, pl. 3, fig. 1-5, 7) of similar age (Volgin 1960, p. 53, pl. 4, fig. 2).

Buxtonia arturi Sarytcheva (1968, p. 117, pl. 13, fig. 1-3, text-fig. 49, 50) from the Upper Carboniferous and possibly Lower Permian Kokpecten Suite of Kazakhstan has

strong radial ribs, and is elongate, again with only a shallow sulcus. *B.*? *levinsonlessingi* Zavodowsky (1970; Abramov & Grigorieva 1983, p. 81, pl. 4, fig. 1-2) from the Middle Carboniferous Davnin Suite of west Verchoyan is large with well formed wide sulcus, which is not as deep as in the Canadian species. The Bashkirian species *Buxtonia gjeliensis* Ivanov (1935, p. 31, pl. 1, fig. 11, pl. 4, fig. 9, 11, 12), also reported in Sarytcheva & Sokolskaya (1952, pl. 102, fig. 17) and Mironova (1967, p. 17, pl. 2, fig. 1) from Bashkiria is large, with closely allied ornament, but no deep sulcus.

From the Visean Windsor Group of Nova Scotia, *Buxtonia cogmagunensis* Bell (1929, p. 118, pl. 18, fig. 13-18) is smaller than *B. sulcata*, and has no more than a shallow impersistent anterior sulcus. Ribbing is comparatively firm.

Buxtonia grandis Sutherland & Harlow (1973, p. 49, pl. 10, fig. 1-8) from Morrowan beds of New Mexico and Oklahoma is moderately close in ornament, and is large, but has scarcely any sulcus, and various specimens not specifically named of Desmoinesian age from New Mexico are no closer in this respect. From the Mississippian Redoak Hollow Formation of Oklahoma, *B. incurvatus* Sutton & Wagner, 1938, from the Clore Limestone of southeast Illinois and western Kentucky and *B. suttoni* Elias, 1957 from the Redoak Hollow Formation of Oklahoma are of upper Mississippian age, and vary slightly in ornament, but none are as large nor have such a well formed ventral sulcus as in the Canadian form. Further species of *Buxtonia* from United States, including *B. incurvata* (Sutton & Wagner), were illustrated by Sutton (1938, pl. 65, fig. 1-6), all but *B. vicinalis* (White) from the Keokuk Limestone appreciably smaller, and none show a deep ventral sulcus comparable with that of the Canadian form.

Chao (1928, p. 57) discriminated a new species *pseudoscabricula* for material ascribed to *scabricula* Martin, 1809 by Chao (1927b, p. 78, pl. 8, fig. 1-3), from the Choniukou Formation of the Gansu areas in northwestern China, on the basis that commarginal rugae were absent, and that spines were more elongate. Further material was added by Wang (1955, p. 156, pl. 90, fig. 1-3); and Wang et al. (1964, p. 277, pl. 42, fig. 13, 14), and Chen & Shi (2003, p. 149, pl. 6, fig. 10, 17, pl. 9, fig. 28). For the latter report on material from the lower Heshilafu Formation of the

Kunlun Mountains, spines are not discussed, and are not revealed in the figures. Chen (2004, p. 437) rated the species as a zonal index, of late early Visean to early middle Visean age.

Subfamily **MARGINATIINAE** Waterhouse, 2002

Genus ***Umboanctus*** Waterhouse, 1971

Diagnosis: Medium size, thick shell, ventral valve sulcate, dorsal valve geniculate, ribs strong, reticulated by closely spaced narrow commarginal rugae over the disc, spines numerous over both valves.

Type species: *Umboanctus spinosus* Waterhouse in Bamber & Waterhouse (1971, p. 212) from Unit 2 (now Blackie Formation), of Bashkirian age, Yukon Territory, OD.

Discussion: This genus resembles *Buxtonia* in some respects, with its spinose and ribbed

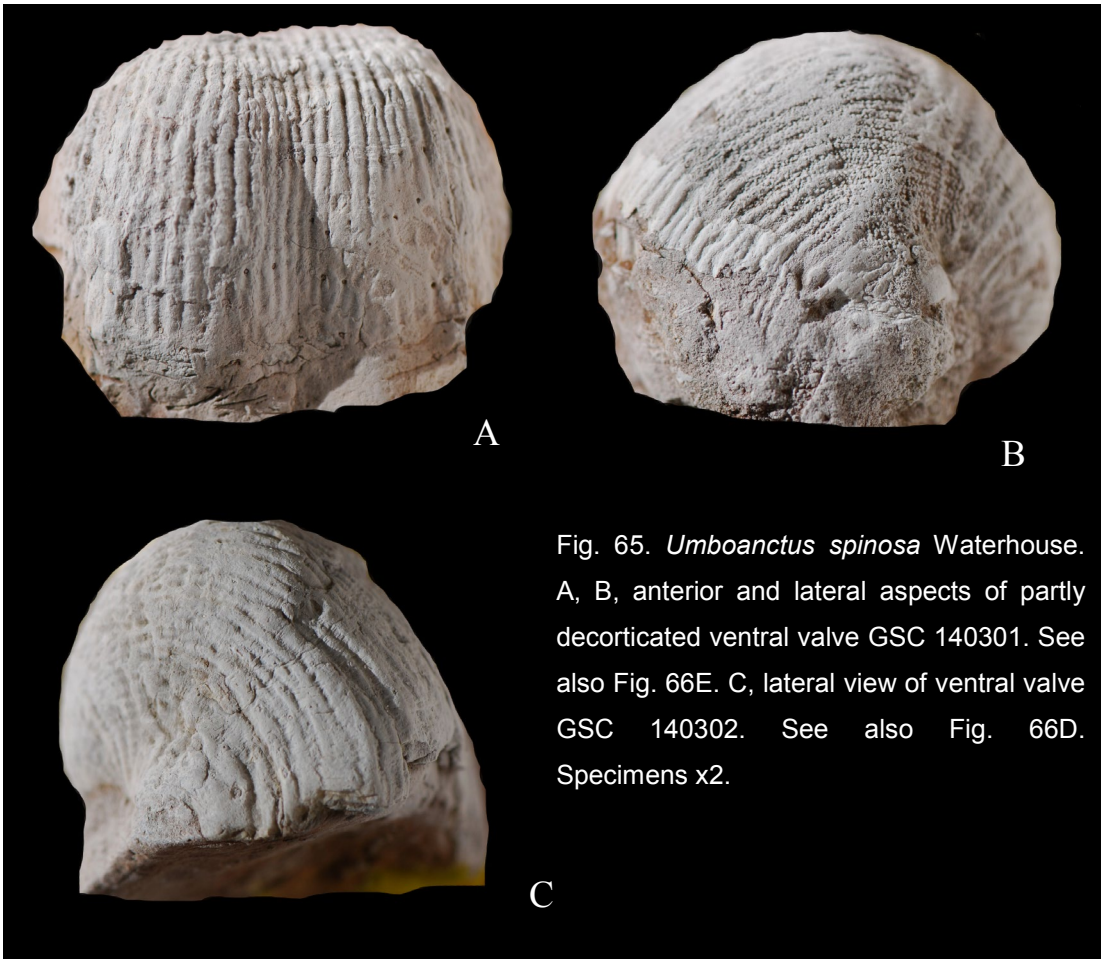


Fig. 65. *Umboanctus spinosa* Waterhouse. A, B, anterior and lateral aspects of partly decorticated ventral valve GSC 140301. See also Fig. 66E. C, lateral view of ventral valve GSC 140302. See also Fig. 66D. Specimens x2.

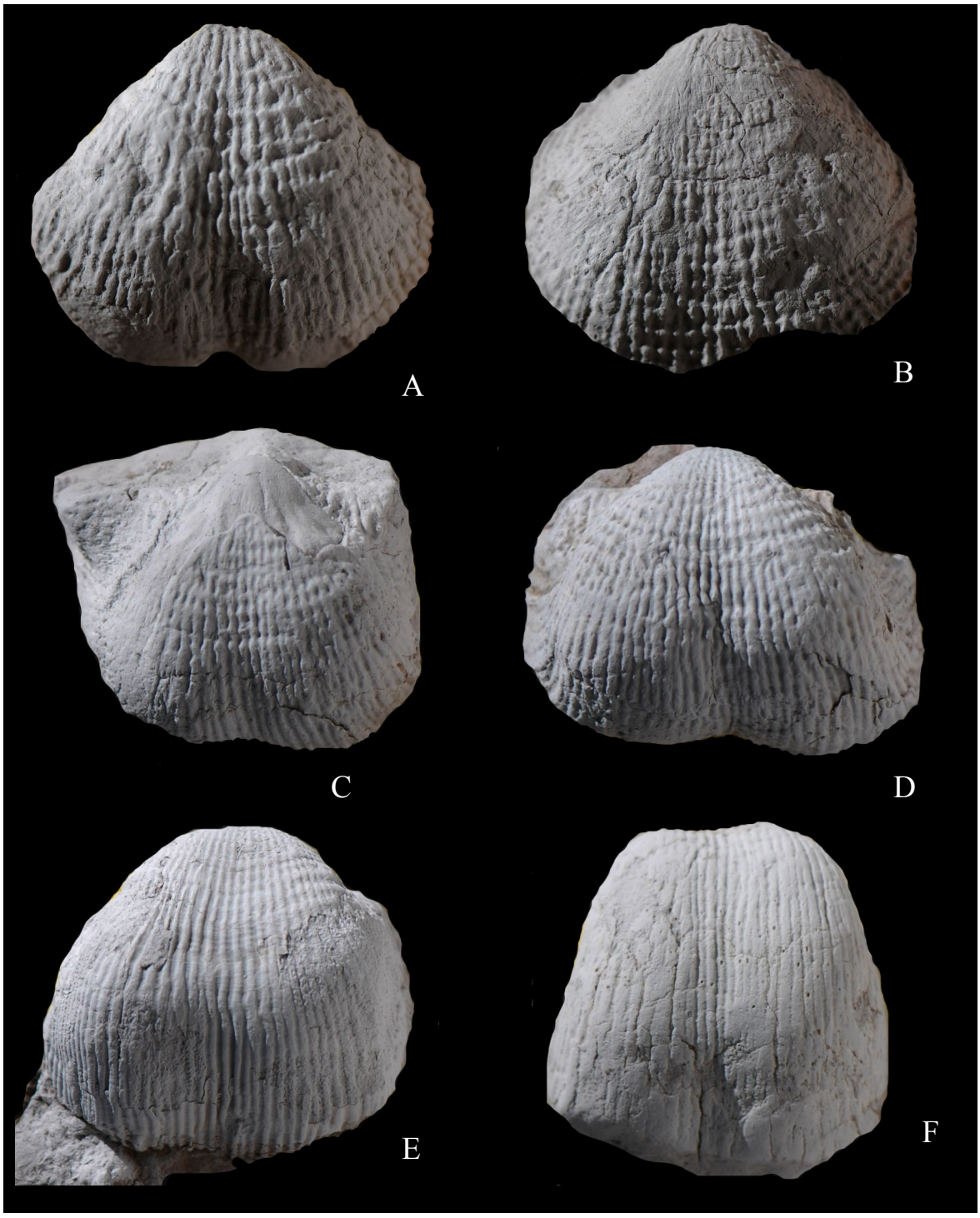


Fig. 66. *Umboanctus spinosa* Waterhouse. Ventral valves x2. A, GSC 140303. B, GSC 140304. C, GSC 140305. D, GSC 140302. See Fig. 65C. E, GSC 140301. F, GSC 140307.

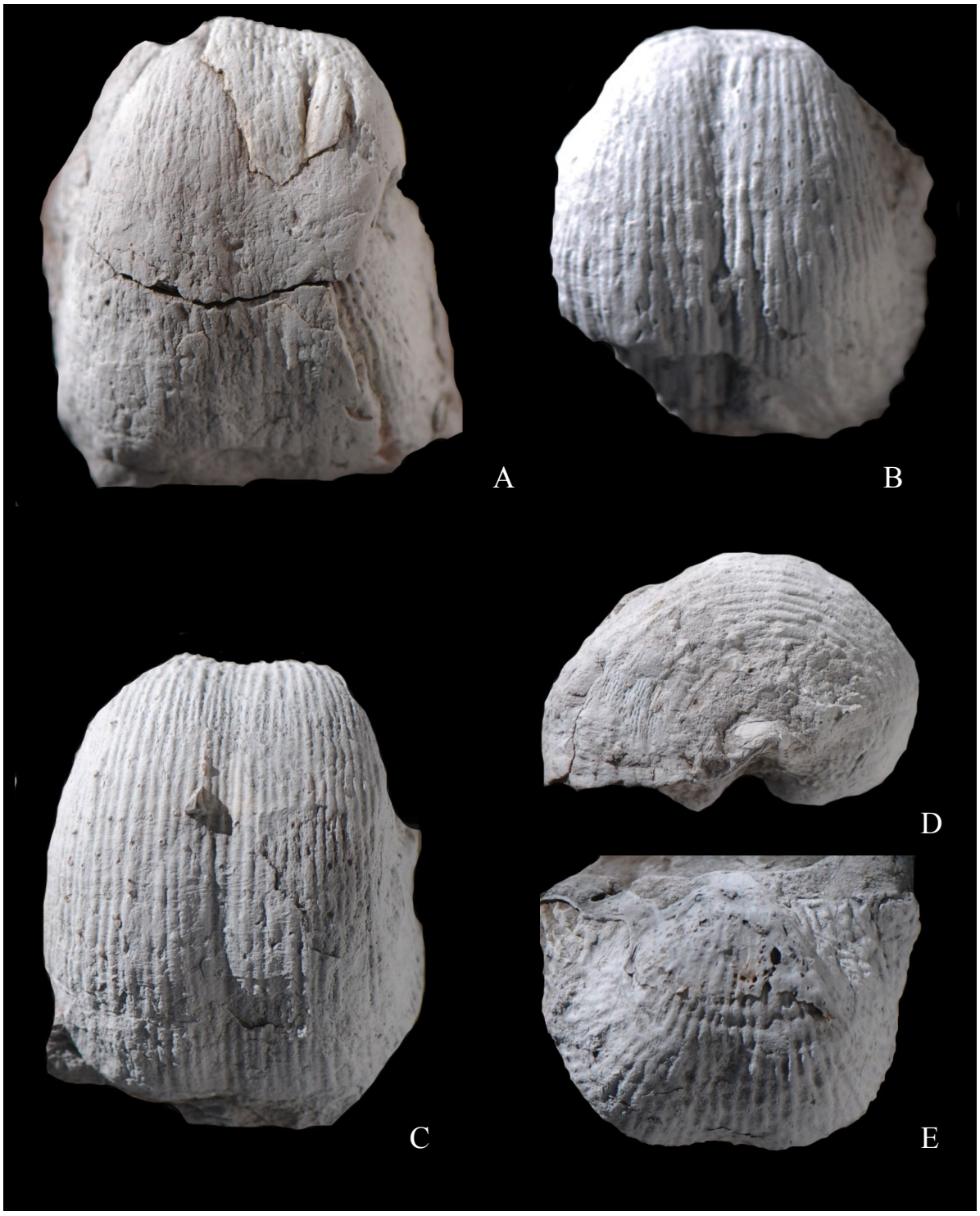


Fig. 67. *Umboanctus spinosa* Waterhouse. A, anterior aspect of partly decorticated ventral valve, GSC 140308. B, D, posterior and lateral aspect of ventral valve GSC 140309. C, anterior view of ventral valve GSC 140310. E, posterior aspect of ventral valve, GSC 140311. Specimens x2, except Fig. 67D, x1.5.

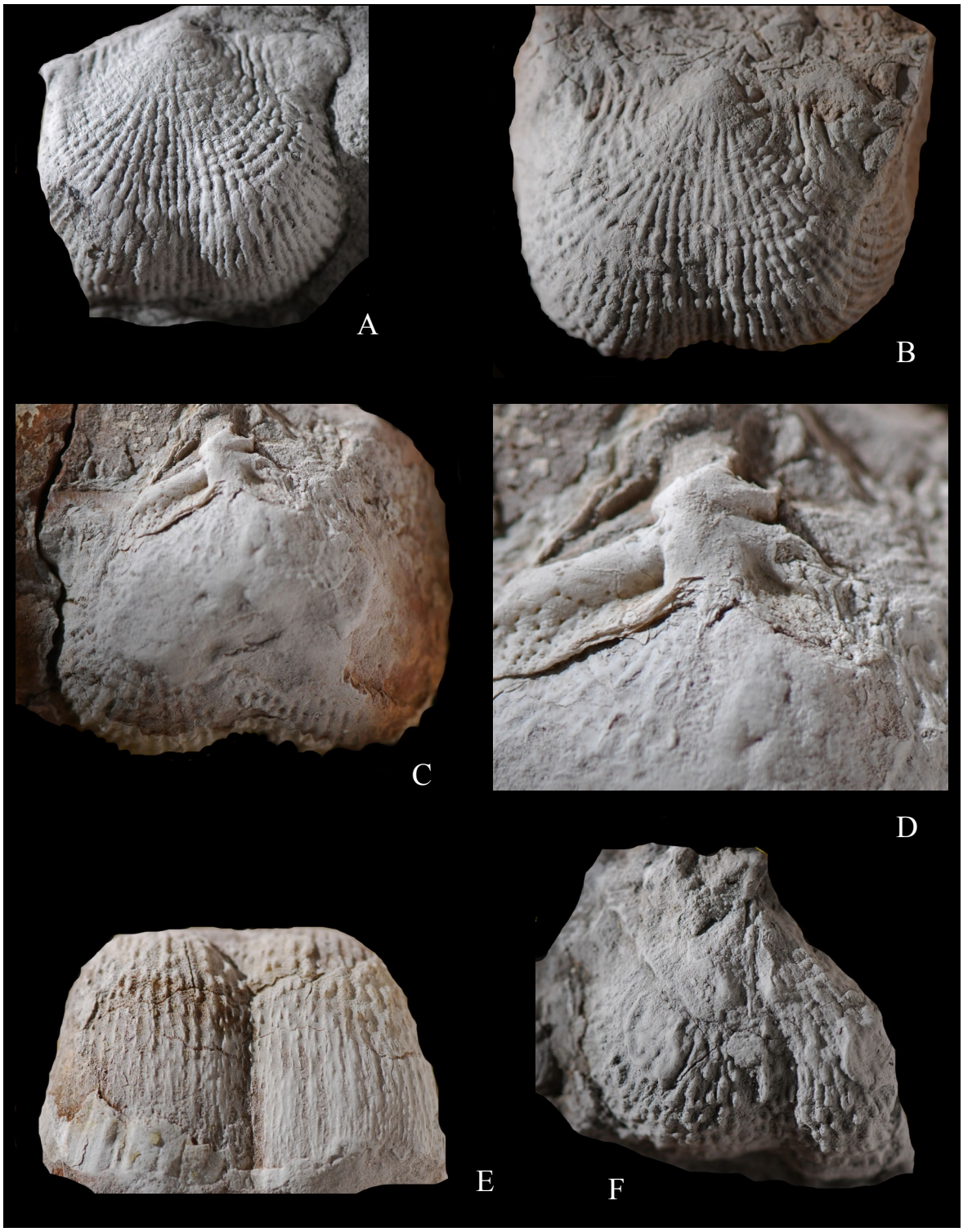


Fig. 68. *Umboanctus spinosa* Waterhouse. A, dorsal external mould GSC 140312. B, dorsal external mould GSC 140313. C, dorsal valve showing cardinal process and damaged external mould, GSC 140312. D, detail of same, x4. E, anterior aspect of same specimen. F, dorsal interior, GSC 140315. Specimens x2, except Fig. 69D, x4.

Fig. 69. *Umboanctus spinosa* Waterhouse. A, dorsal external mould, GSC 140316 x2, B, dorsal internal mould with ventral umbonal shell and anterior shell attached, GSC 140317 x1.5.

Fig. 70. *Umboanctus spinosa* Waterhouse. A, external mould of dorsal valve, GSC 140318. B, dorsal view of specimen with valves conjoined, GSC 140304. See Fig. 66B. C, dorsal external mould, GSC 140319. Specimens x1.5.

ornament, but ribs are more prominent, and spines somewhat fewer. The species at Peel River is distinctly smaller, with stronger ribs and shallow sulcus compared with the species of *Buxtonia* from the same outcrops. Internally, large pustules are restricted to the posterior dorsal trail, at least until late maturity, and brachial shields are clearly defined, unlike those of *Buxtonia.*

Umboanctus spinosus Waterhouse, 1971

Fig. 65 - 73

1971 *Umboanctus spinosus* Waterhouse, p. 212, pl. 25, fig. 1-10.
2000 *U. spinosus* – Brunton et al., p. 508, Fig. 347.2a-e.

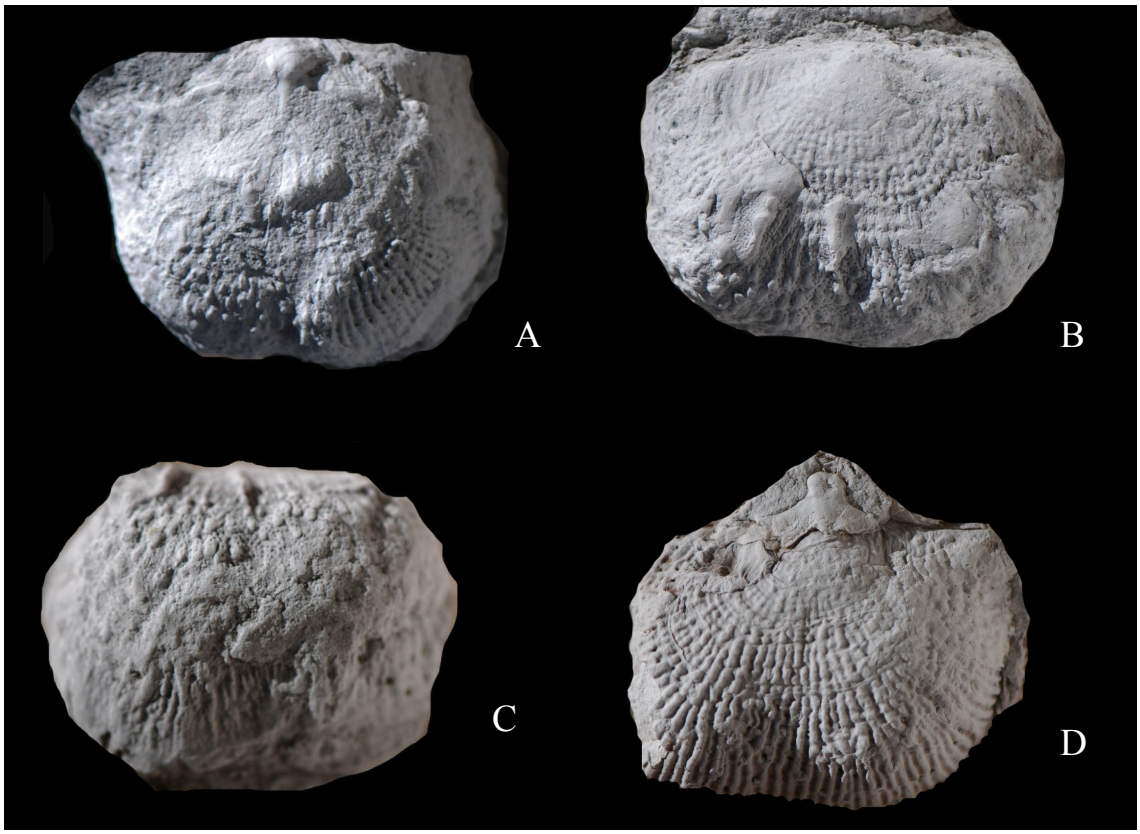


Fig. 71. *Umboanctus spinosa* Waterhouse. A, dorsal internal mould GSC 140320, showing somewhat damaged muscle platform and cardinal process. B, C, dorsal external mould posteriorly with anterior median septum and damaged brachial shields, and C, anterior aspect showing trail, GSC 140321. D, dorsal valve showing cardinal process and external mould, GSC 140322. Specimens x2.

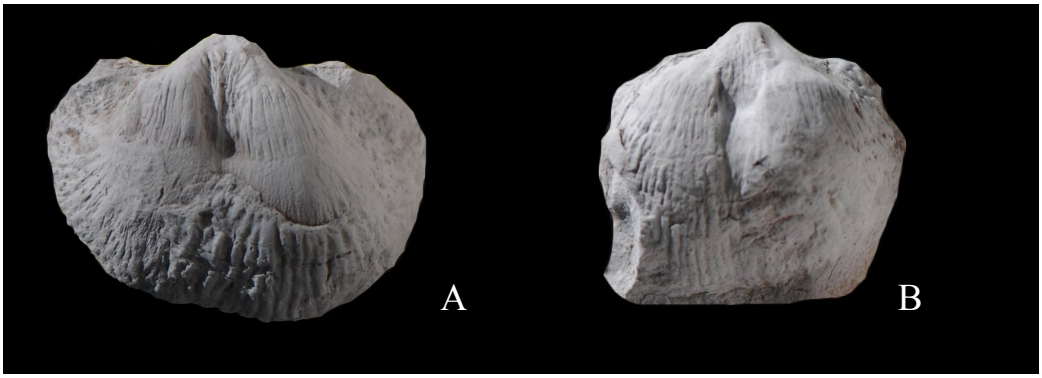


Fig. 72. *Umboanctus spinosa* Waterhouse. A, part internal mould of ventral valve, GSC 140323, showing muscle scars. B, internal mould of ventral valve GSC 140324, showing muscle scars. Specimens x1.25.

Fig. 73. *Umboanctus spinosa* Waterhouse, part of internal mould of ventral valve GSC 140325 with posterior shell stripped back to expose adductor scars, x4.

Diagnosis: As for genus.

Holotype: Specimen GSC 26411, figured in Bamber & Waterhouse (1971, pl. 25, fig. 3, 6) and Brunton et al. (2000, Fig. 347.2b, c), from JBW locality 200 (see p. 185).

Material: Fifty ventral valves, twenty eight dorsal valves and four specimens with valves conjoined

Description: Illustrations of this species are provided, based on material from the south bank of the Peel River, with improved documentation of dorsal exteriors.

Superfamily **ECHINOCONCHOIDEA** Stehli, 1954

Family **ECHINOCONCHIDAE** Stehli, 1954

Subfamily **ECHINOCONCHINAE** Stehli, 1954

Tribe **ECHINOCONCHINI** Stehli, 1954

Genus ***Calliprotonia*** Muir-Wood & Cooper, 1960

Diagnosis: Small to median in size, spines of two sizes over commarginal bands on each valve, marginal ridge high.

Type species: *Calliprotonia renfrarum* Muir-Wood & Cooper, 1960, p. 247 from the Finis Shale (Upper Pennsylvanian), Texas, United States, OD.

Calliprotonia sp.

Fig. 74

Material: One ventral valve.

Description: The specimen is a worn internal mould, and shows, poorly, the commargons each bearing a band of spines, consisting of two or three rows of slightly coarser spines, behind one or rarely two rows of finer spines.

Fig. 74. *Calliprotonia* sp., anterior aspect of ventral internal mould GSC 140326 x3.

Suborder STROPHALOSIIDINA Waterhouse, 1975

Superfamily **STROPHALOSIOIDEA** Schuchert, 1913

Family **STROPHALOSIIDAE** Schuchert, 1913

Subfamily **ECHINALOSIINAE** Waterhouse, 2001

Tribe **ECHINALOSIINI** Waterhouse, 2001

Echinalosiin gen. & sp. indet. A

Fig. 75

Material: Two internal moulds and an obscure mould of ventral valves with one external fragment, and an external fragment of a dorsal valve. A small echinalosiin spat (see Waterhouse 1959) is attached to *Levipustula* (Fig. 79B).

Description: The larger ventral internal mould is 29mm wide, 24mm long and 12mm high, with gently arched non-sulcate visceral disc, apparently obtuse cardinal extremities, broad ventral umbo, only moderately wide hinge and maximum width near mid-length. No cicatrix is visible on the internal mould, which shows two roundly subtriangular and raised adductor scars. Diductor scars are subrounded and well impressed, overlapping the anterior half of the adductor scars.

Much of the valve floor is covered by fine pustules, and there are traces of spine bases, with a few spines opening into the interior over the anterior shell. The spines appear to lie in quincunx and along commarginal rows, spaced at three in 5mm towards the anterior margin. The fragment of a ventral external mould has moderately well defined commarginal laminae, and sturdy erect spines arranged in quincunx. The dorsal fragment shows much finer erect spines, well spaced, over the anterior half. The dorsal valve shell is moderately concave, as in typical Echinalosiini.

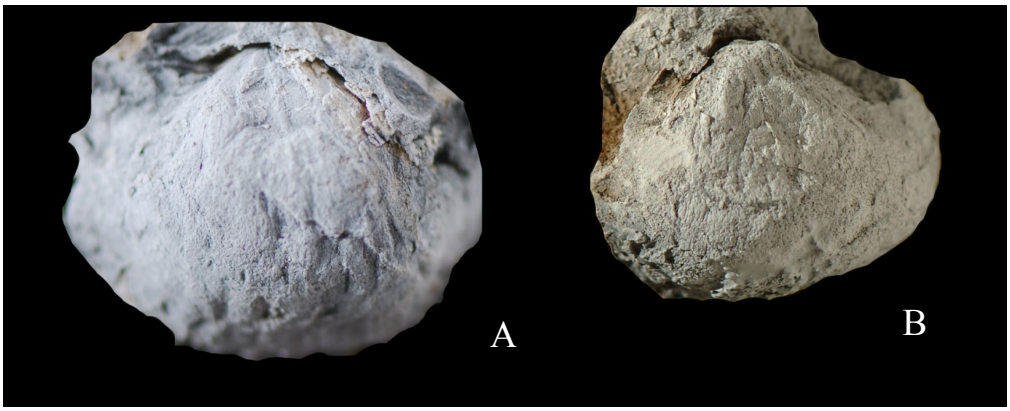


Fig. 75. Echinalosiin gen. & sp. indet. A. A, ventral internal mould GSC 140327, x1.5, 2. B, ventral internal mould GSC 140328, x3.

Resemblances: The small fragment of a dorsal exterior has well defined erect spines, which strongly suggest a position within Dasyalosiidae Brunton, and shape and ventral spines indicate a position within Echinalosiiinae Waterhouse, as based on *Echinalosia* Waterhouse, 1967, but preservation is too poor to determine if any spines were prostrate. Members of Quadratiinae Lazarev (see Waterhouse 2013, p. 234) have more smoothly convex ventral valve, and have rare or no dorsal spines. A report on fossils from “Unit 2” in Waterhouse (1968c) mentioned the genus *Heteralosia* King, which implies that the dorsal valve in specimens lacked dorsal spines as in Strophalosiinae, but these specimens are not available, and their position unconfirmed.

Superfamily **SCACCHINELLOIDEA** Licharew, 1928a, b

Family **LEVIPUSTULIDAE** Lazarev, 1985

[Nom. promoveo hic ex Levipustulinae Lazarev, 1985, p. 72]

Subfamily **LEVIPUSTULINAE** Lazarev, 1985

Diagnosis: Externally subwaagenoconchiform, with lateral buttress supports in the dorsal valve, extending each side of dorsal adductors. No interareas, no cicatrix, trail very short. Spines over both valves subprostrate or erect especially around margins. Ventral and dorsal spines over the disc may be sharply recurved in the shell and form spine tunnels, extending forward from the spine base through the shell, and these are left as grooves in internal moulds. Cardinal process with tall median pillar or shaft.

Discussion: Examination of Canadian material, and reassessment of material assigned to *Levipustula* Maxwell and *Lanipustula* Klets shows a hitherto unsuspected relationship to Tribe Balkhasheconchini Waterhouse, 2002b, p. 25, elevated to a subfamily in Waterhouse (2013, p. 256; 2018, p. 182). Members of Balkhasheconchinae externally resemble Waagenoconchinae Muir-Wood & Cooper, 1960, but have buttress plates in the dorsal valve and recurved spines over the ventral but not the dorsal disc. The presence of buttress plates strongly suggests a relationship to Scacchinelloidea Licharew, 1928a, b, as explained by Waterhouse (2018, p. 181ff). Genera in Balkhasheconchinae include *Balkhasheconcha* Lazarev, *Buxtoniella* Abramov & Grigorieva and *Ramaliconcha* Waterhouse. Lazarev (1985) and Brunton et al. (2000, p. 518) placed constituent genera of Balkhasheconchinae within Tribe Waagenoconchini, but members of this group lack buttress plates and have no recurved ventral disc spines, so that the similarity is superficial. The external ornament for *Levipustula* consists of ventral spines with shorter external bases than in members of Balkhasheconchinae, and internally, the spine tunnels are much more conspicuous, leaving long grooves over the interior ventral valve (see Fig. 78, herein and McKellar 1965, pl. 2, fig. 11a) and over the dorsal interior, though previously overlooked.

Araksalosiinae Lazarev, 1989 has disc and trail spines over the ventral valve externally like those of Balkhasheconchinae, and internally displays lateral buttress plates. Araksalosiinae clearly differs from *Balkhasheconcha* and allies in having interareas, teeth and sockets, a row of strong ventral hinge spines in several genera, and lack of recurved spines and spine tunnels. Araksalosiin genera are of Upper Devonian (Famennian) to Lower Carboniferous (lower

Tournaisian) age, whereas *Campbelliconcha*, a descendent which lost interareas and teeth, but retained the buttress plates, is of Visean age. The closest of known Araksalosiinae likely to have provided a progenital source is *Hamlingella* Reed, 1943 of upper Devonian age. This species has moderately strong hinge spines, fine spines on both valves and similar dorsal interior with dendritic posterior dorsal adductors and long lateral buttress plates.

Buttress plates were supposed to have been lacking from Lanipustulini Waterhouse, 2013, p. 61, yet this seems to have been contradicted in the Waterhouse text, with the comment that *Lanipustula* has buttress plates, as confirmed for *L. baicalensis* (Maslennikov), figured by Kotlyar & Popeko (1967) and Klets (2005. pl. 8). The other genera mentioned in the discussion, *Impiacus* Lazarev & Suur'suren, *Jakutoproductus* Kashirtsev and *Verchoyania* Abramov, do lack buttress plates, and are assigned to Absenticostini Waterhouse, 2002b, which remains a member of Plicatiferinae Muir-Wood & Cooper, 1960 in Family Overtoniidae Muir-Wood & Cooper, 1960, as classified by Taboada & Shi (2011).

Genus ***Levipustula*** Maxwell, 1951

Diagnosis: Gently concavo-convex profile, semirecumbent spine bases in quincunx over ventral valve, spines numerous over ears, dorsal spines erect, scattered. Posterior interior of ventral valve with low long ridges and grooves, forming spine tunnels that extend forward from posteriorly prolonged spine bases, and spine tunnels also present in dorsal valve.

Type species: *Levipustula levis* Maxwell, 1951, p. 10 from Pennsylvanian of Neerkol, Queensland, OD.

Discussion: This genus has been recently discussed by Taboada & Shi (2011), and several further matters may be discussed. The age of the type species, and possibly of its occurrences throughout east Australia require consideration. Although Maxwell (1951, 1964), McKellar (1965) and Roberts et al. (1976) preferred a Moscovian age, as in Brunton et al. 2000, the assessment based on associated brachiopods co-occurring in the Poperima Formation in the Yarrol Basin of Queensland is unconvincing (Maxwell 1964, Table 2), not that this is final. Extensive subsequent collections made by the Geological Survey of Queensland have never been systematically

examined. Better age data in New South Wales, based on the ammonoid *Cravenoceras kullatiensis* Campbell, and a SHRIMP age (Roberts et al. 1995), whilst not conclusive, suggest a Namurian age, and Roberts (1981, Fig. 3; 1985, Fig. 38, p. 106) showed the *Levipustula levis* Zone as lower to mid-Namurian. It is far from clear whether the *Levipustula levis* faunas of eastern Australia persisted until Moscovian time, or whether any post-Bashkirian marine faunas developed in eastern Australia until the entry of the *Auriculispina levis* Zone, deemed to be of Late Carboniferous (?Gzhelian) age (Engel 1975, 1980, Waterhouse 1987). Overall, much remains remains to be done to clarify the Late Carboniferous marine faunas of eastern Australia and their correlations. But *Levipustula*-like shells have been reported in the Yukon Territory of Canada from Ettrain faunas by Nazer (1978), and are likely to be of Kasimovian age.

There have been varying interpretations of the relationship between Australian *Levipustula* and material from western Europe and eastern Russia. Klets (1983) assigned *Pustula baicalensis* Maslennikov, 1960 from Lake Baikal to a new genus *Lanipustula*, and its validity has been defended by a number of authors, including Brunton et al. (2000, p. 453) and Taboada & Shi (2011). The latter authors offered a very extensive survey, and concluded that although most of the attributes used by authors to distinguish the two genera had limited validity and owed much to either misinterpretation or to infrasubspecific variation, the two genera could be distinguished by the greater density of spines on the dorsal valve of *Laniproductus,* and indeed a tendency for no spines to be present over the dorsal disc of *Levipustula*. They recognized both genera in east Australia, and assigned material from New South Wales (such as material assigned to *Levipustula levis* by Campbell 1961, pl. 56, fig. 18) to *Laniproductus*, rather than *Levipustula*. In my assessment, the differences in dorsal spination are not great and the number and density of dorsal spines do not appear to have been completely consistent, as judged from assessment of figures which suggest that disc spines are fine on the dorsal valves of the type species for each genus, and tend to be only 1mm or rarely up to 1.5mm apart. Not all *Lanipustula* from northeast Russia show dorsal disc spines, and some *levis* do suggest dorsal disc spines (Taboada & Shi 2011, Fig. 8C, E, Fig. 9I). But it must be allowed that interpretation of small scale figures presents difficulties, and future studies would be much more enlightening if illustrations were at a larger

size, and if actual dimensions and spacings for dorsal spines were provided, an omission yet to addressed by those concerned with first-hand re-examination of the species concerned. Comparable differences in other genera, such as *Echinalosia* for example, would not necessarily rate more than specific distinction. There are various dorsal valves assigned to type *Levipustula* which appear to have no spines, others with a few, and others with rather more (see Taboada & Shi 2011, Fig. 8E for instance). Some *Lanipustula* have few dorsal spines (see Klets 2005, pl. 8, fig. 9, for example, for a specimen assigned to the type species). A specimen of *Lanipustula* figured by Klets (2005, pl. 8, fig. 9) as *Lanipustula baicalensis* (Malsennikov) shows spines over the trail that are distinctly coarser than those over the disc, but whether this applies to topotype *Lanipustula* is uncertain. The trail appears to be very low or scarcely preserved in *Levipustula levis* from Queensland by Taboada & Shi (2011), and no detail on dorsal spinosity, and no measurements of density counts have been published by any author.

As well as discounting the validty of *Lanipustula*, I now reject genus *Austroboreas* Waterhouse, based on *Lanipustula kletsi* Taboada & Shi, 2011, p. 103 from the Las Salinas Formation of Argentina. It is *Levipustula*, and I judge the claim that it was typified by buttress plates as misguided. The species described as *Levipustula breimeri* Winkler Prins (1968, pl. 5, fig. 1, 2) from the Escalada Formation of Spain is probably *Tuberculatella* Waterhouse. Two Belgium species of Westphalian age that were described by Waterlot (1932) have been compared with *Levipustula* by some authorities, but neither are deemed to be congeneric. *Productus* (*Pustula*) *piscariae* Waterlot (1932, p. 164, pl. 3, fig. 3-11) looks close to *Flexaria*, and *P.* (*P.*) *rimberti* Waterlot (1932, p. 168, pl. 4, fig. 1-9) is close to *Pustula*.

Finally, there are intriguing developments within at least the posterior interior of the visceral disc that have hitherto escaped notice. These are closely spaced radiating ridges and grooves, illustrated for the specimens herein, and also well developed in *Levipustula baicalensis* (Malsennikov), as well figured by Klets (1983, 2005, pl. 8, fig. 2b) and more obscurely indicated but definitely present in *Levipustula levis* figured by Maxwell (1951, pl. 2, fig. 4c; 1964, pl. 7, fig. 19), and Taboada & Shi (2011, pl. 6B, E, pl. 10K). These appear to be caused by spine tunnels, extending forward from the spine base, at least for the ventral valve (see Fig. 78, 79C). They

provide a link with Balkhasheconchinae Waterhouse, which has well developed ventral spine tunnels of similar nature, as illustrated in Waterhouse (2018, Fig. 152, p. 188). Unlike any member of Balkhasheconchinae, dorsal valves also display spine tunnels on internal moulds, but so far no connection between the tunnels and dorsal spines has been established.

Levipustula canadensis n. sp.

Fig. 76 - 79

Derivation: Named from Canada.

Diagnosis: Ventral spines well spaced. Dorsal spines numerous and erect.

Holotype: Specimen GSC 140332 illustrated in Fig. 76D, here designated.

Material: Eight ventral valves, mostly internal moulds, and a dorsal valve with part of the ventral valve.

Description: Specimens are small, the most complete internal mould measuring 26mm wide, 23mm long and 9mm high. The ventral umbo is extended a little beyond the hinge, slightly incurved, with posterior walls gently convex in profile and persisting to approximately mid-length, at maximum width. Ears are moderately large, gently convex and with weakly acute cardinal extremities. The valve is moderately convex, with no sulcus and weak median flattening as a rule, although a few specimens are more highly arched, a small ventral valve measuring 7.5mm wide, 8mm long and 4mm high. This specimen displays external ornament, and as it clearly differs in shape from the others, might be a variant or subspecies. There are low commarginal rugae at the lateral margins. Some (only some) slightly worn shells show fine riblets, two or three per mm. Comparatively large spine bases lie in rough quincunx over the valve, with broad swollen bases nearly two mm long, and one specimen shows about nine erect spines over the ear. Some internal moulds have fine riblets, two in 1mm, and spine bases are comparatively large and prolonged for up to 3mm. Internally over the disc the spines arise from long spine tunnels up to 7mm long extending forward from the spine base, whereas the trail lacks tunnels.

The posterior shell has secondary thickening, with commarginal fine grooves, each side of moderately prominent oval adductor scars bearing irregular longitudinal ridges and grooves,

but diductor scars are not clearly visible.

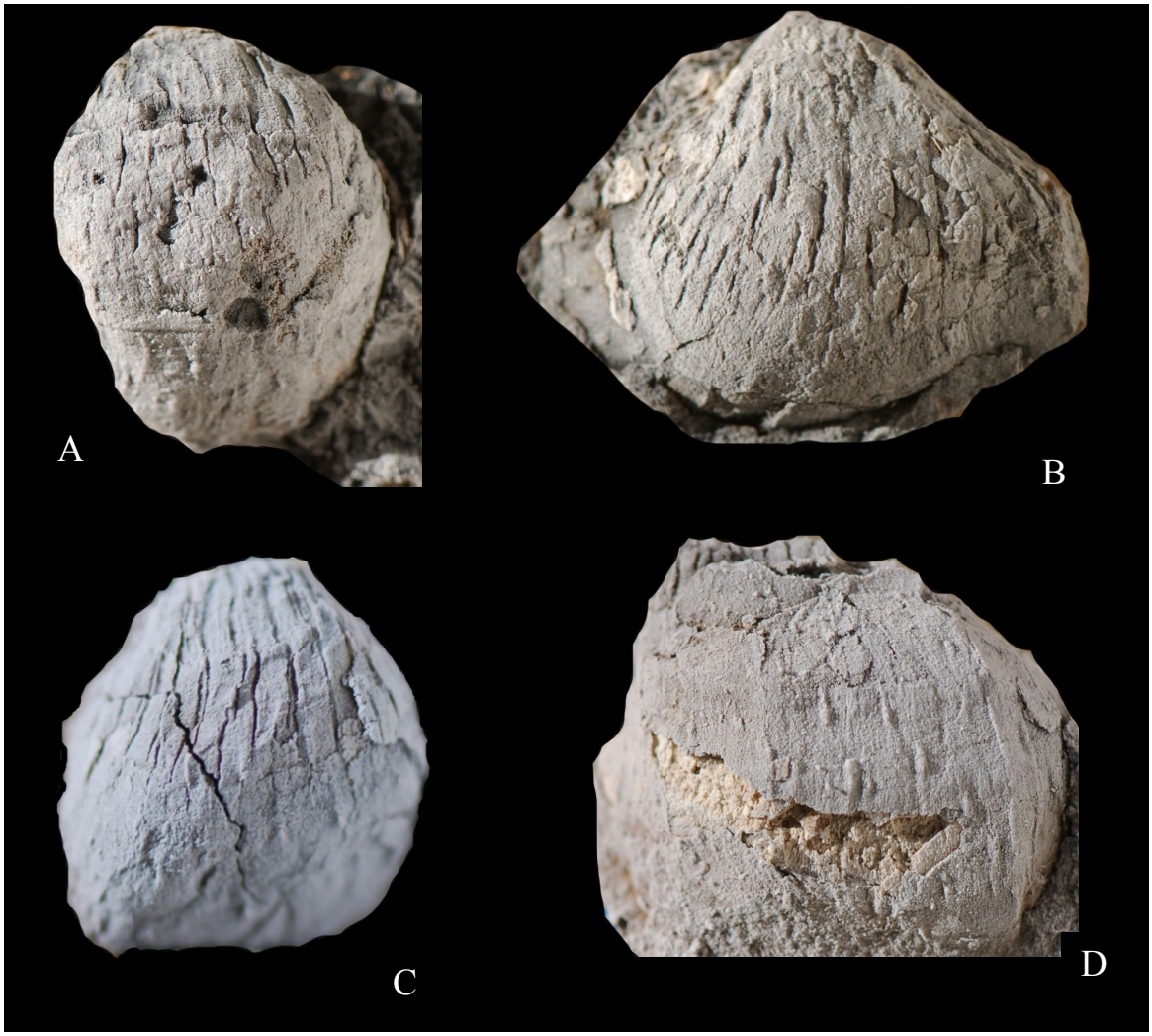


Fig. 76. *Levipustula canadensis* n. sp. A, ventral internal mould GSC 140329. B, ventral internal mould, GSC 140330. C, ventral internal mould GSC 1403331. Spine tunnels are well displayed in these specimens. D, slightly worn ventral shell, anterior view of holotype GSC 140332, showing typically well spaced ventral spines and light inner ribs anteriorly. Specimens x3.

The specimen preserved chiefly as a dorsal valve has the ventral umbonal shell preserved in matrix, and shows that the body corpus was relatively thick (Fig. 77B). The dorsal valve is partly decorticated to show the external mould, over which spine bases are numerous, 0.1 to 0.15mm in diameter, and generally 0.8mm apart, and spaced often at less than 1mm apart in a shell 26mm wide. Small pustules cover much of the dorsal disc, and form a few rows of larger

pustules over the anterior disc, near the start of the trail, with a row of large pustules, nine in 5mm, just before the geniculation. The trail is abruptly curved, and spines over the first-formed part of the dorsal trail are distinctly larger than those over the disc, and appear to have been semi-recumbent. But little of the trail is preserved, and the diameter of most trail spines uncertain, although many of those that may be discerned appear no larger than those over the disc. In addition, spine tunnels are apparently absent from the trail.

Resemblances: The ventral spines of specimens from the Yukon Territory are slightly better spaced than in the type and allied material figured as *Levipustula levis* Maxwell from the lower Pennsylvanian of Queensland by Taboada & Shi (2011), and pustules over the dorsal internal disc are coarser and fewer, except close to the geniculation, and the trail is comparatively short. Similar differences apply to *L. patagoniensis* Simanauskas, 1996, p. 303, Fig. 3A-E from the Pampa de Tepuel Formation of Patagonia, and ranging into the lower Las Salinas Formation.

Fig. 77. *Levipustula canadensis* n. sp. A, dorsal valve, GSC 140333, part interior, partly decorticated to show exterior with hollows representing erect spine bases, x3. B, same specimen with outlines in black, showing the posterior height of the visceral corpus V between the ventral valve and the dorsal valve. Some of the numerous spine bases are enhanced by black dots within two of the three decorticated areas (enclosed by dashes), within the shell. Specimens x3.

Fig. 78. *Levipustula canadensis* n. sp., slightly worn ventral shell, GSC 140334, shown by local equalization, x4. Slender spine tunnels shown as dark lines extend in front of arched spine bases.

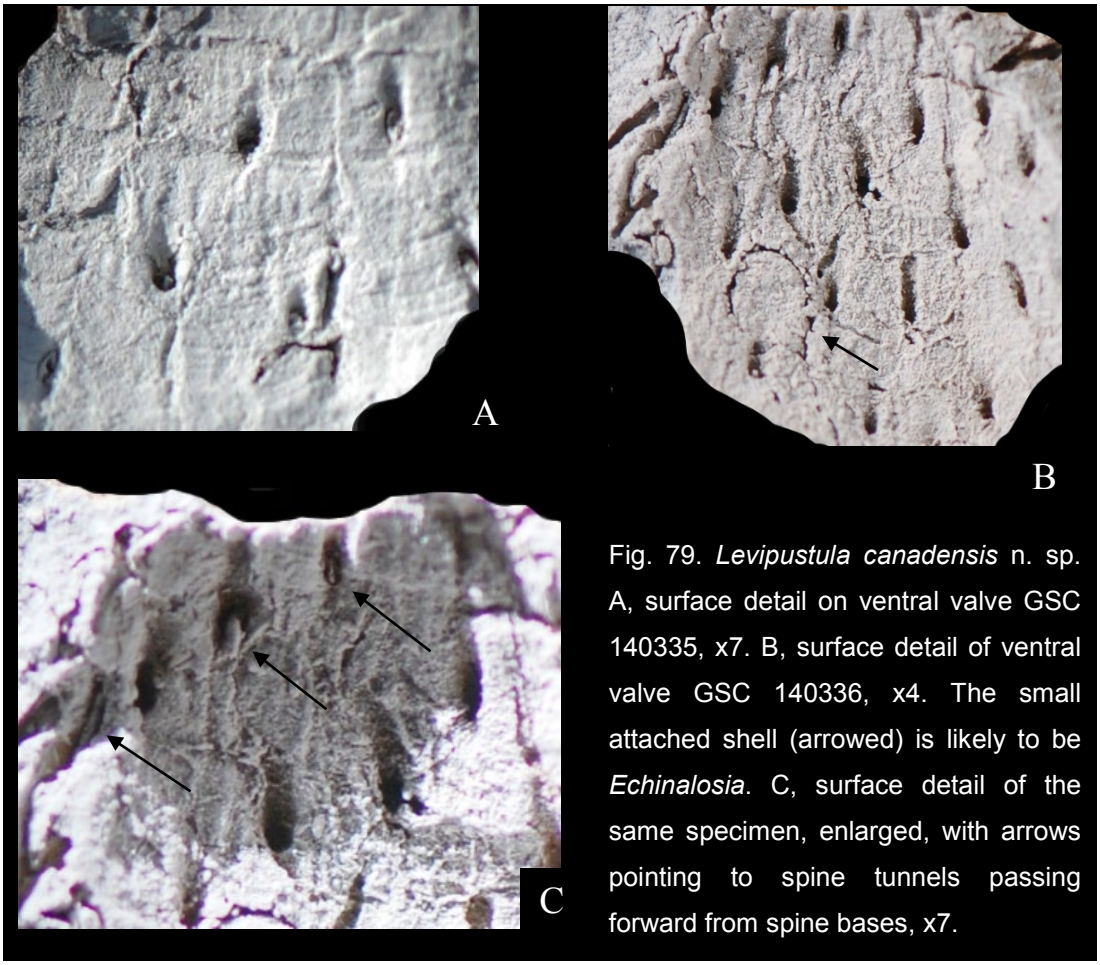


Fig. 79. *Levipustula canadensis* n. sp. A, surface detail on ventral valve GSC 140335, x7. B, surface detail of ventral valve GSC 140336, x4. The small attached shell (arrowed) is likely to be *Echinalosia*. C, surface detail of the same specimen, enlarged, with arrows pointing to spine tunnels passing forward from spine bases, x7.

Type *Lanipustula baicalensis* (Maslennikov, 1960), as well figured by Klets (2005, pl. 8, fig. 9) from northeast Russia, has stronger but more closely spaced ventral spines over the disc and trail, and dorsal spines over the trail are stronger than those of the dorsal disc. The Las Salinas species of Argentina, described as *Lanipustula kletsi* Taboada & Shi (2011, Fig. 11), has closely spaced ventral spines, and comparatively coarse dorsal spines that are semi-recumbent over at least the anterior disc. Full comparison is difficult, because the ventral ears and dorsal interior are not well preserved in the present species, but the spacing of its ventral spines is distinctive. All these species are regarded as belonging to *Levipustula*.

Subfamily **CAMPBELLICONCHINAE** n. subfam.

Name genus: *Campbelliconcha* Waterhouse, 2013, p. 260 from Visean of New South Wales, here designated.

Diagnosis: Dorsal buttress plates, numerous ventral spines with only slightly elongated bases, dense and evenly spaced and erect over the dorsal valve. Distinguished from other genera in the family by the lack of internal tunnels extending from the spine bases of either valve.

Discussion: *Campbelliconcha* Waterhouse, 2013, p. 260, type species *Waagenoconcha delicatula* Campbell, 1956 from Visean faunas of New South Wales, Australia, has very small ventral spines with very short bases posteriorly, and erect spines anteriorly. In view of the presence of well developed buttress plates, a distinctive spine pattern, and lack of visible tunnels in the interior (Campbell 1956, Roberts 1964), it is placed in a separate unit, likely to have been ancestral to *Levipustula*. Balkhasheconchinae is distinguished from Levipustulinae by its longer ventral spine bases, and by the absence of tunnels related to dorsal spines, as far as known, and Levipustulinae has spine tunnels in both valves. All three subfamilies are classed in Family Levipustulidae Lazarev, and all three lack the interareas and teeth typical of the precursor group, Araksalosiinae in Araksalosiidae.

Suborder LINOPRODUCTIDINA Waterhouse, 2013

Superfamily **PAUCISPINIFEROIDEA** Muir-Wood & Cooper, 1960

Family **ANIDANTHIDAE** Waterhouse, 1968a

Subfamily **ANIDANTHINAE** Waterhouse, 1968a

Tribe **MEGOUSIINI** Waterhouse, 2018

Diagnosis: Ears where large project laterally and then curve forward.

Name genus: *Megousia* Muir-Wood & Cooper, 1960, p. 309 from Wordian of Texas, OD.

Discussion: Genera include *Megousia* Muir-Wood & Cooper, *Kuvelousia* Waterhouse, *Mongousia* Manankov and probably *Akatchania* Klets. Members are restricted to the northern paleohemisphere, and apparently evolved from *Pseudomarginifera* Stepanov or more likely *Protoanidanthus* Waterhouse, in view of the short ventral ears, and the considerable time range for the latter genus. Dorsal ears in Anidanthini, which includes *Anidanthus* Booker, *Anidanthia* Waterhouse and *Fusiproductus* Waterhouse, extend laterally, without curving forward.

Megousiin? gen. & sp. indet.

Fig. 80

Material: A ventral valve, part exterior, part internal, and second ventral fragment.

Fig. 80. Megousiin? gen. & sp. indet., ventral valve GSC 140337, largely decorticated but with remnants of external ornament, x2.

Description: The more complete specimen is 28mm wide, 20mm long and 12mm high, with broad incurved umbo of angle at 100°, and hinge at maximum width of the shell. Ears are of small size for the subfamily, and could have been broken short. The shell is well inflated, with shallow median sulcus commencing at the umbonal tip with angle of approximately 37°. The trail curves

evenly forward from the disc, and with the disc is covered by fine ribs at seven in 5mm. Rare erect spines are visible anteriorly, but hinge or ear spines are not revealed. Internally the adductor platform is elongate and apparently smooth.

Resemblances: The specimen is too incomplete to identify, though the build of the valve suggests *Kuvelousia* or ally. Although the ears as preserved are much shorter than in *Megousia*, *Kuvelousia*, and allies, they could have been broken short. Members of the tribe are rare in beds of this age, and only became more common in later Carboniferous and Permian faunas.

Family **YAKOVLEVIIDAE** Waterhouse, 1975

Subfamily **MUIRWOODIINAE** Waterhouse, 2013

Diagnosis: Strut spines well developed, usually two up to six. Ventral marginal ridge not conspicuous.

Discussion: Muirwoodiinae is readily distinguished from Yakovleviinae Waterhouse by the presence of strut spines, and from Paramarginiferinae Lazarev through the lack of strong marginal ridges. These subfamilies and their relationship to Paucispiniferoidea are further discussed in Waterhouse (2013).

The assertion by Kotlyar (1961) that *Muirwoodia* Licharew, 1947 was junior synonym of *Yakovlevia* Fredericks, 1925 was accepted by Cooper & Grant (1975, p. 1178) and Brunton et al. (2000, p. 465). But her conclusion was opposed by Kalashnikov (1980), Abramov & Grigorieva (1983, p. 92), Lazarev (1990) and Klets (2005), and the difference in spination confirms the distinction, *Yakovlevia* and allied genera lacking the large long erect strut spines found in *Muirwoodia* and allies.

Genus ***Muirwoodiciana*** n. gen.

Name: Named for H. M. Muir-Wood.

Diagnosis: Shaped like *Muirwoodia*, ventral strut spines in pairs at cardinal extremities, and across anterior disc, often as two pair with one pair on lateral slopes, the other close to the sulcus, with further and finer spines. Distinguished by development of dorsal spines.

Type species: *Muirwoodiciana inexpectans* n. gen., n. sp. from the lower Blackie Formation (Bashkirian) at Peel River, Yukon Territory, here designated.

Discussion: This genus is outstanding amongst genera in the family, through having rare and scattered dorsal spines, and so is the yakovleviid equivalent of *Mongousia* Manankov, 2008, which is the only genus within Anidanthidae to have dorsal spines. Shells are shaped like those of *Sajakella* Nasikanova, 1968, and strut spines are found at the cardinal extremities, anterior lateral flanks, and anterior slopes near the sulcus of the ventral valve.

Muirwoodiciana inexpectans n. gen., n. sp.

Fig. 81 - 83

Derivation: inexpectans – unexpected, Lat.

Diagnosis: Moderately large with strong ribs.

Holotype: Specimen GSC 140343 figured in Fig. 82A-D, here designated.

Material: Nine ventral valves, two dorsal valves and two specimens with valves conjoined, with other fragments.

Dimensions in mm:

Width	Length	Height
36	19	6
39	25	9 dorsal valve

Description: The specimens are transverse with gently convexo-concave disc and long trail, which in one specimen is 19mm long in a conjoined specimen 30mm wide that has lost its outer ears. The ventral umbo projects a little beyond the hinge, with umbonal angle between 80^{o} and 90^{o}, and the hinge lies at maximum width, with a very low if any ginglymus. The ears are large and gently convex, projecting at maximum width, with acute cardinal extremities measuring 50^{o}. The dorsal valve is similar, with umbo not extending beyond the hinge and no visible ginglymus. The anterior disc curves abruptly into a long trail. The ventral sulcus commences at or just front of the umbonal tip, and widens at an angle of 20^{o}, with narrowly concave floor, and sides are parallel over the trail. The dorsal fold commences midway over the disc and persists over the trail. In one specimen the fold narrows and becomes higher anteriorly. Costae are well defined,

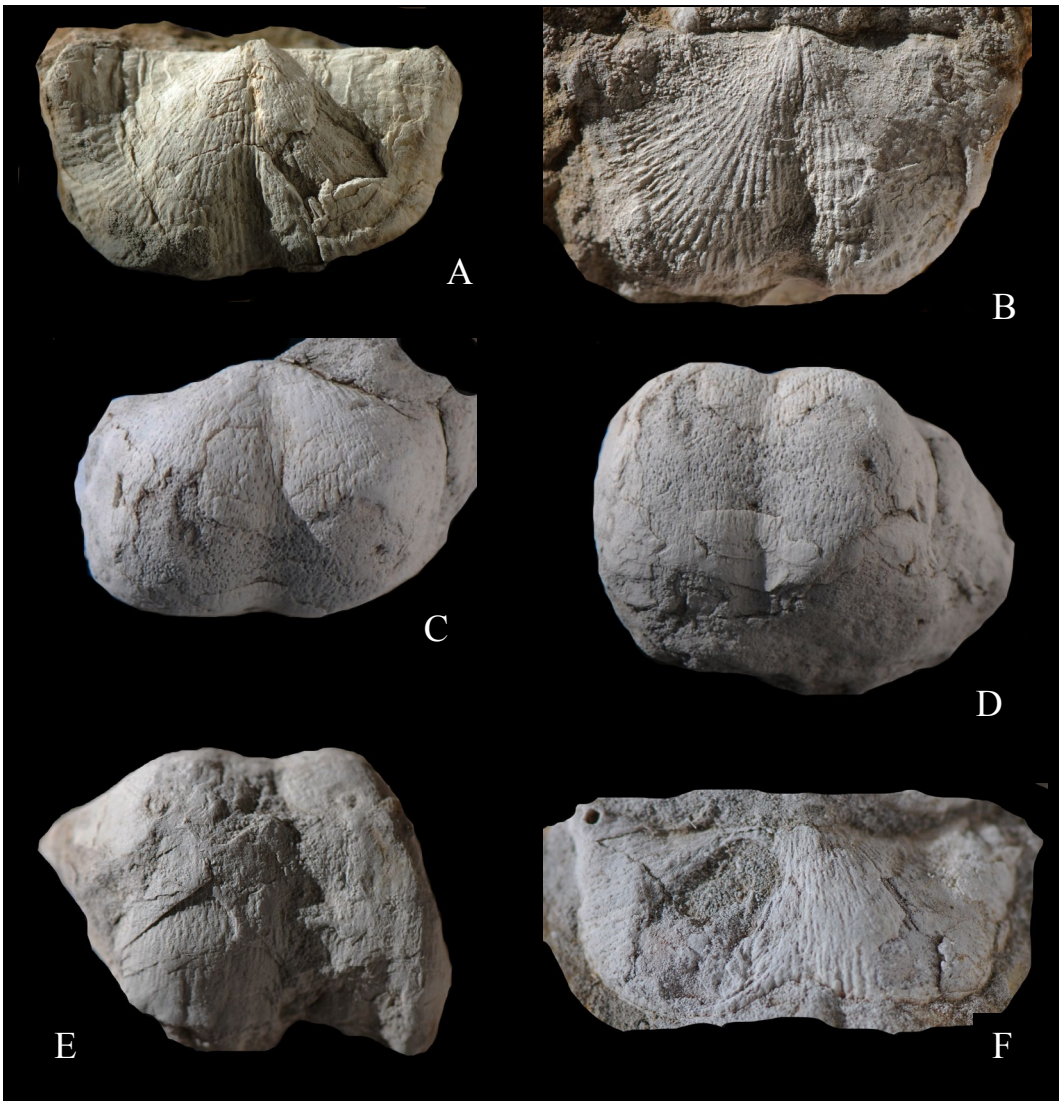


Fig. 81. *Muirwoodiciana inexpectans* n. gen., n. sp. A, ventral aspect of specimen with valves conjoined, GSC 140338. B, ventral disc, GSC 140339. C, D, ventral disc and ventral trail of ventral valve, GSC 140340. E, anterior aspect of ventral valve, GSC 140341. F, ventral disc of highly transverse specimen GSC 140342, showing prominent cardinal strut spine. Specimens x2.

numbering six in 5mm towards the anterior disc of the ventral valve, with frequent branching. They increase in strength on large specimens to number four or five in 5mm over the anterior disc and trail. The dorsal costae are of similar strength and appear to be either intercalated or branching.

There is a row of well spaced and not very large spines along the ventral hinge, and a

large strut spine is sited just in front of the hinge on the outer ears. As a rule, two pairs of strut spines lie over the anterior disc, one pair at the outer edge of the sulcus and another aligned and more laterally placed, and in one specimen, a third pair lies further from the sulcus to form a row of three each side of the sulcus. There are also signs of one or two slightly finer spines nearer to the umbo. A few other finer spines are scattered over the disc and trail, in no perceptible pattern. It is the dorsal valve which is of exceptional interest. The small specimen with valves conjoined appears to show a sturdy spine over the anterior disc, close to the fold, as well as indefinite further spines. The large external mould shows scattered erect spines with matrix-filled cores over the subgeniculation and anterior trail, arising from the crests of costae without change to the strength of the rib, and they are sturdy, without being as strong as the strut spines.

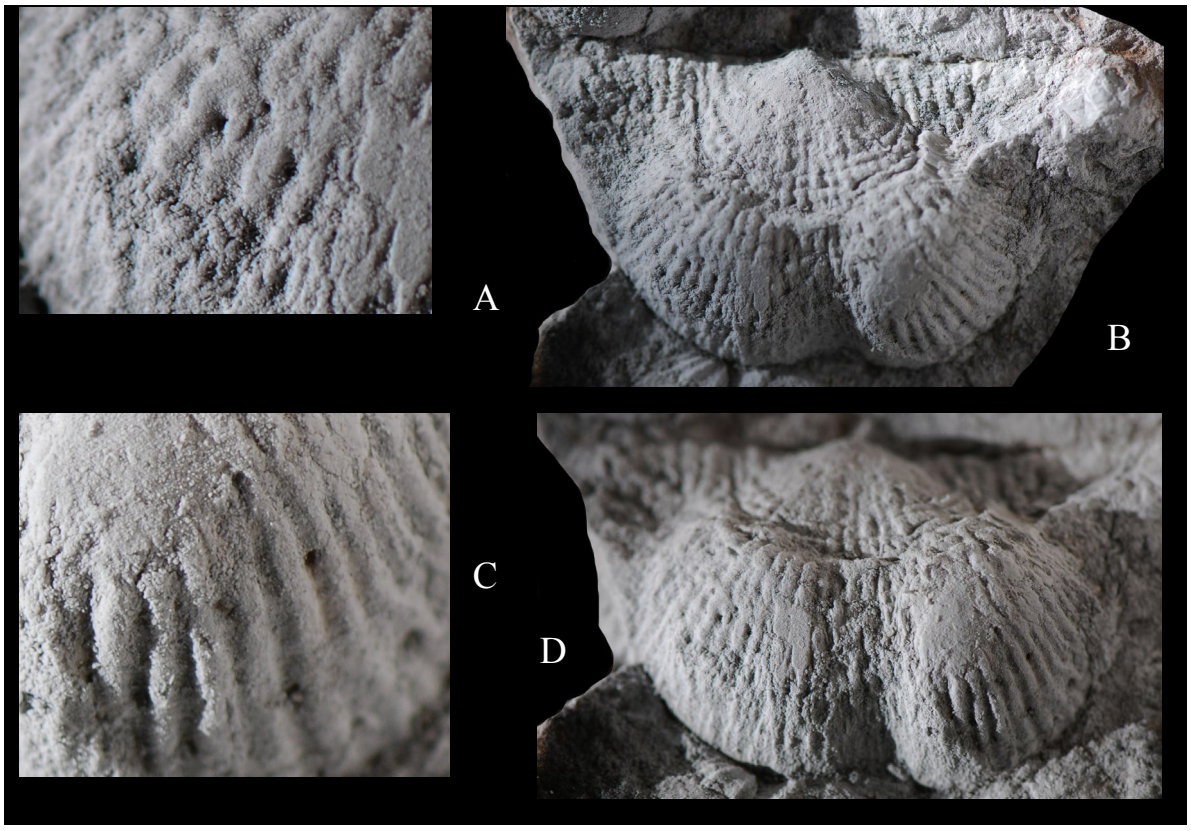


Fig. 82. *Muirwoodiciana inexpectans* n. gen., n. sp. dorsal external mould showing scattered spines as dark hollows entering the matrix, holotype GSC 140343. A, C, parts of anterior dorsal mould, x20 approx., showing hollows leached in the surrounding matrix from dorsal spines. B, D, disc and anterior aspects of the dorsal internal mould, x2.

Fig. 83. *Muirwoodiciana inexpectans* n. gen., n. sp. decorticated dorsal exterior GSC 140344, x2. Costae branch in this specimen.

Resemblances: An Upper Carboniferous specimen figured from west Verchoyan by Abramov & Grigorieva (1983, pl. 10, fig. 13) as *Muirwoodia mammatiformis* Licharew is transverse and alate like this species, but there is no indication of dorsal spines. The only other yakovleviid found so far to have dorsal spines is the slightly older species described as *Muirwoodiciana* n. sp. from the underlying Hart River Formation in the Yukon Territory, deemed to be most likely of late Visean (Ealy Carboniferous) age (see p. 34). This species is more transverse with larger ears, regular commarginal rugae and finer costae, and less regularly arranged strut spines, although both share the cardinal pair. On this form, dorsal spines are erect and slender, but little material is available.

Superfamily **LINOPRODUCTOIDEA** Stehli, 1954

Family **LINOPRODUCTIDAE** Stehli, 1954

Diagnosis: Shells oval in outline, transverse or elongate, usually symmetrical and free-living, umbo prominent, ears developed, venter arched. Ventral spines only, none equivalent to strut spines, shell often large, body cavity deep or shallow, both valves with fine close-set regular radial ornament, commarginal ornament inconspicuous. Cardinal process large, outer lobes not fused dorsally.

Linoproductid gen. & sp. indet.

Fig. 84

Material: An external mould of a dorsal valve.

Description: The specimen is about 66mm wide (adjusted for loss of shell on one side), 55mm long and at least 23mm high, with broad dorsal umbo, moderately wide hinge at 41mm, small concave ears, and broad shallow fold which arises near the posterior third of the shell and extends forward at an angle close to 40^{o}. Evenly developed costellae cover the valve except for the ears, increasing by intercalation, and as wide as the interspaces, fine ribs along the middle of a number of the interspaces anteriorly suggest that the ribs were in the process of further increase by intercalation. The disc is crossed by low rugae and growth stops, at slightly irregular intervals of generally four, up to six mm. The trail is over 25mm high and curves gradually from the disc. There are no dorsal spines.

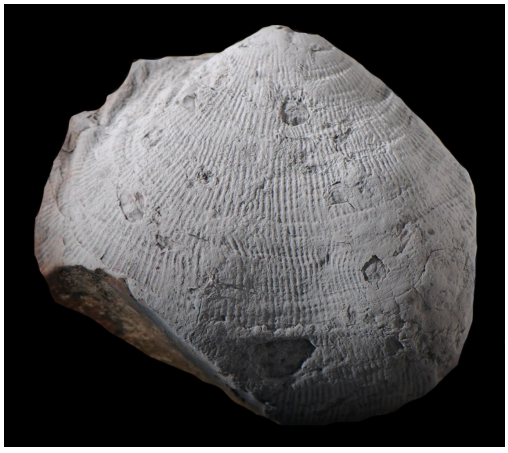


Fig. 84. Linoproductid gen. & sp. indet., dorsal valve external mould, GSC 140345, x1.

Family **SCHRENKIELLIDAE** Lazarev, 1990

Subfamily **SCHRENKIELLINAE** Lazarev, 1990

Diagnosis: Large shells with short trail continuing in plane of disc and virtually imperceptible externally. Row of ventral spines, spines present in some genera over ventral disc and trail.

Discussion: Members of this subfamily are found chiefly in the Pennsylvanian of United States, with some Canadian representation, and have only a short trail, unlike Chhidrusiinae Waterhouse, 2013 of the Salt Range in Pakistan, which has a very long trail.

Genus ***Praeschrenkiella*** Waterhouse, 2013

Diagnosis: Large transverse shells with ventral spines in row along hinge and in a few anterior rows.

Type species: *Praeschrenkiella waddingtonae* Waterhouse 2013, p. 381 from Member A (Gzhelian), Jungle Creek Formation, Yukon Territory, Canada, OD.

Praeschrenkiella? sp. indet.

Fig. 85, 86

Material: A ventral valve, and possible fragment of a second specimen.

Description: The more complete specimen is 69mm wide with hinge 49mm wide, and estimated to have been nearly 40mm long, and 6mm high. The umbo extends slightly beyond the hinge with angle of 110°, and the hinge is wide, with maximum width lying close to mid-length, much

Fig. 85. *Praeschrenkiella*? sp., ventral valve GSC 140346 x1.5.

wider than that of the linoproductid described previously. There is no sulcus, but the disc is less convex over the middle of the shell, and ears are large and very gently convex, with wide cardinal angle of 120°. Costellae are fine, seven occurring in 5mm anteriorly, and increase by intercalation

and anteriorly by branching. Spines about 1mm in diameter form a row along the hinge, and small spines arise from the crest of a number of ribs, over what may be the imperceptible start of a trail. The spines cover all of the fragment of the other specimen and most are arranged in bands. Some of the spines lie at the start of branches in the ribs. Its identity is insecure, because it has a narrow sulcus not visible in the better preserved specimen, but there is some variation in the presence or absence of a fold and sulcus in the related genus *Schrenkiella* (see Waterhouse 2018, p. 253). The nature of the spines is not like that commonly found in Linoproductidae, and is closer to the pattern observed in *Praeschrenkiella*.

Fig. 86. *Praeschrenkiella*? sp., ventral valve GSC 140347 x5, showing fine holes in surrounding matrix, caused by leached-out spines. Orientation is open to question: the ribs may have become finer anteriorly or posteriorly, and the sulcus may have deepened or shallowed anteriorly.

Family **OVATIIDAE** Lazarev, 1990

Subfamily **OVATIINAE** Lazarev, 1990

Genus ***Ovatia*** Muir-Wood & Cooper, 1960

Ovatia? sp.

Fig. 87

Material: A ventral valve.

Description: The specimen is small and elongate, 13mm wide and 15mm long and 7.5mm high, strongly arched, with incurved ventral umbo, steep posterior walls and small ears bearing low

commarginal rugae. There is no sulcus or median flattening, and only very faint signs of a few commarginal rugae over the disc. Ornament consists of fine radial ribs, about two in 1mm, and scattered fine erect spines with short or no prolonged bases, and no sign of the aureoles seen in some species. Ear spines are poorly shown, and are at least nine in number.

Fig. 87. *Ovatia*? sp., ventral valve GSC 140348, x4

Resemblances: *Ovatia* is thought to have been restricted largely to the Mississippian, although Grigorieva in Sarytcheva (1977a, p. 165, pl. 17, fig. 12, 13) reported a possible Middle Permian (Kazanian) species with a query from the Russian Arctic. A shell illustrated as *Ovatia* from the Hart River Formation in Bamber & Waterhouse (1971, p. 114, pl. 1, fig. 18, 19) is broader and less arched than the present specimen.

Superfamily **PROBOSCIDELLOIDEA** Muir-Wood & Cooper, 1960

Family **PAUCISPINAURIIDAE** Waterhouse, 1986

Subfamily **MAGNIPLICATININAE** Waterhouse, 2001

Tribe **MAGNIPLICATININI** Waterhouse, 2001

Subtribe **CANCRINELLINAI** Waterhouse, 2013

Discussion: This is a rare subtribe, in which members are closely related to Magniplicatinai in Magniplicatini Waterhouse, but lack the strong commarginal rugae over the ventral disc which typify members of that subtribe. Only three genera have so far been described, *Cancrinella*

Fredericks, *Calytrixia* Waterhouse and *Platycancrinella* Waterhouse, and these are of Permian age, all found in paleolatitudes of moderately high paleolatitudes, in Russia, and in the perigondwanan realm of the Himalaya and Western Australia, the latter position consonant with being a southern hemisphere equivalent in paleolatitude to that of northern Canada.

Cancrinellin? gen. & sp. indet.

Fig. 88

Fig. 88. Cancrinellin? gen. & sp. indet., ventral valve GSC 140349, x5.

Material, Description: A small elongate ventral valve, measuring 7mm wide, 10mm long and 4.5mm high, has three to four fine capillae per mm, and well formed commarginal rugae laterally, though the venter is smoothly rounded without rugae. Only one specimen is available, and that may not be enough not enough to secure subtribal placement. Spine bases are arranged in quincunx, and are twice as wide as the capillae and somewhat elongate.

Superorder RHYNCHONELLIFORMI Kuhn, 1949

Order RHYNCHONELLIDA Kuhn, 1949

Suborder RHYNCHONELLIDINA Kuhn, 1949

Superfamily **RHYNCHOPOROIDEA** Muir-Wood, 1955

Family **RHYNCHOPORIDAE** Muir-Wood, 1955

Subfamily **TRETORHYNCHIINAE** Savage, 2002b

Genus ***Mysteronia*** n. gen.

Derivation: mystes – priest of the mysteries, Lat.

Diagnosis: Small subtriangular shells with strong branching costae, normal sulcus and fold, arched plate over delthyrium. Moderately strong dental plates, shallow septalium within cardinal plate, subdivided by median sturdy ridge, and without cover plate. Punctae well developed.

Type species: *Mysteronia mysticus* n. gen. n. sp. from Blackie Formation, Yukon Territory.

Discussion: *Rhynchopora* has long been understood as a punctate member of Rhynchonellida in Carboniferous and Permian time, and regarded as the sole genus of the subfamily, or accompanied by *Tretorhynchia* Brunton, 1971. Variation in the cardinalia of shells assigned to *Rhynchopora* has been discussed on pp. 42-45. In some shells, the cardinal plate is subdivided, illustrated by Kozlowski (1914, Fig. 22a), as in a specimen assigned to *R. palumbula* by Cooper & Grant (1976, pl. 696, fig. 8, 11). In others, such as *R. palumbula* Cooper & Grant (1976, pl. 696, fig. 13), the cardinal plate bears a median ridge. The present specimens have a cardinal plate with a shallow septalium which bears a median ridge. Unlike the arrangement in *Rhynchopora*, there is no cover plate, so that the new genus is classed as Tretorhynchiinae. The shell is more triangular in outline than in *Tretorhynchia*, which tends to be bisulcate until maturity, or *Rhynchopora*, which generally displays a rounded subpentagular shape. In *Rhynchopora*, the anterior margins are steep and high, whereas anterior shell of the two valves in present specimens converge at a low angle, just as in *Tretorhynchia*. Compared with *Rhynchoporusia* n. gen. recognized for material from the Hart River Formation, *Mysteronia* is more triangular in shape, with stronger and more branching costae, stronger punctae, and stronger dental plates. None of the somewhat related genera have the strong median ridge along the mid-line of the septalium that is found in *Mysteronia.*

Material for the present genus is far from abundant, but is so distinctive that they are used as the basis for a new genus. One critical factor is the possibility that profile may have changed in late maturity, and that cannot be ruled out until further material is discovered.

Mysteronia mysticus n. sp.

Fig. 89 – 92

Derivation: mysticus – of secret rites, mystic, Lat.

Diagnosis: Subtriangular with strong lateral costae, four or more finer sulcal costae and five costae over the fold, moderately coarse and strongly bifurcated, well spaced punctae. Dental plates well developed, socket plates not crenulate, median broad cardinal plate with shallow median trough bearing strong cardinal ridge, no cover plate.

Holotype: Specimen GSC 140351 illustrated in Fig. 91, 92A, B, here designated.

Material: Two specimens preserved as internal and external moulds, and a dorsal valve, with poorly exposed other specimens.

Description: Specimens triangular with rounded anterior lateral margins, maximum width placed well forward, and wide anterior margin. The ventral umbo is elongate and pointed, with small rounded terminal foramen, and long posterior walls extending well forward, and diverging at 90^{o} to 100^{o}, and in the former case with slightly outward concavity. There is a high narrow delthyrium, with narrow area each side, and closed by a deeply concave plate. The dorsal umbo is broader with angle of 100^{o} to 110^{o}, and much less attenuated. The dorsal valve is nearly twice as high as the ventral valve over the disc. The ventral sulcus widens at 40^{o}, with slight irregularity in the larger specimen, because the paired bordering ribs diverge at 30^{o}, and one of the ribs is narrower than the other and the anterior sulcus extends laterally beyond it on one side. The other and smaller conjoined specimen has a slightly narrower sulcus, and anteriorly the sulcus incorporates a bifurcate bordering rib on each side, and an additional intercalated rib near the anterior margin. The sulcal floor is comparatively flat. The dorsal fold is broad with flat floor, not elevated posteriorly, but becoming prominent anteriorly. The ribs are strong and arise at the ventral and dorsal umbones without any smooth portion. There are three narrow but high ribs posteriorly within the sulcus of the larger specimen, and the lateral bordering rib branches once. In the other specimen, there are two median ribs and each bordering rib branches, with an intercalated rib anteriorly. In the dorsal valve, five ribs extend over the fold on the larger specimen, with two having split just in front of the hinge. The fold ribs of the smaller specimen show complex and asymmetrical branching, as shown in Fig. 92B. Lateral ribs are stronger, numbering four or five on the ventral valve and four or three on the dorsal valve, there being a degree of asymmetry, with anterior branching better developed on the smaller specimen. Crests are narrow and

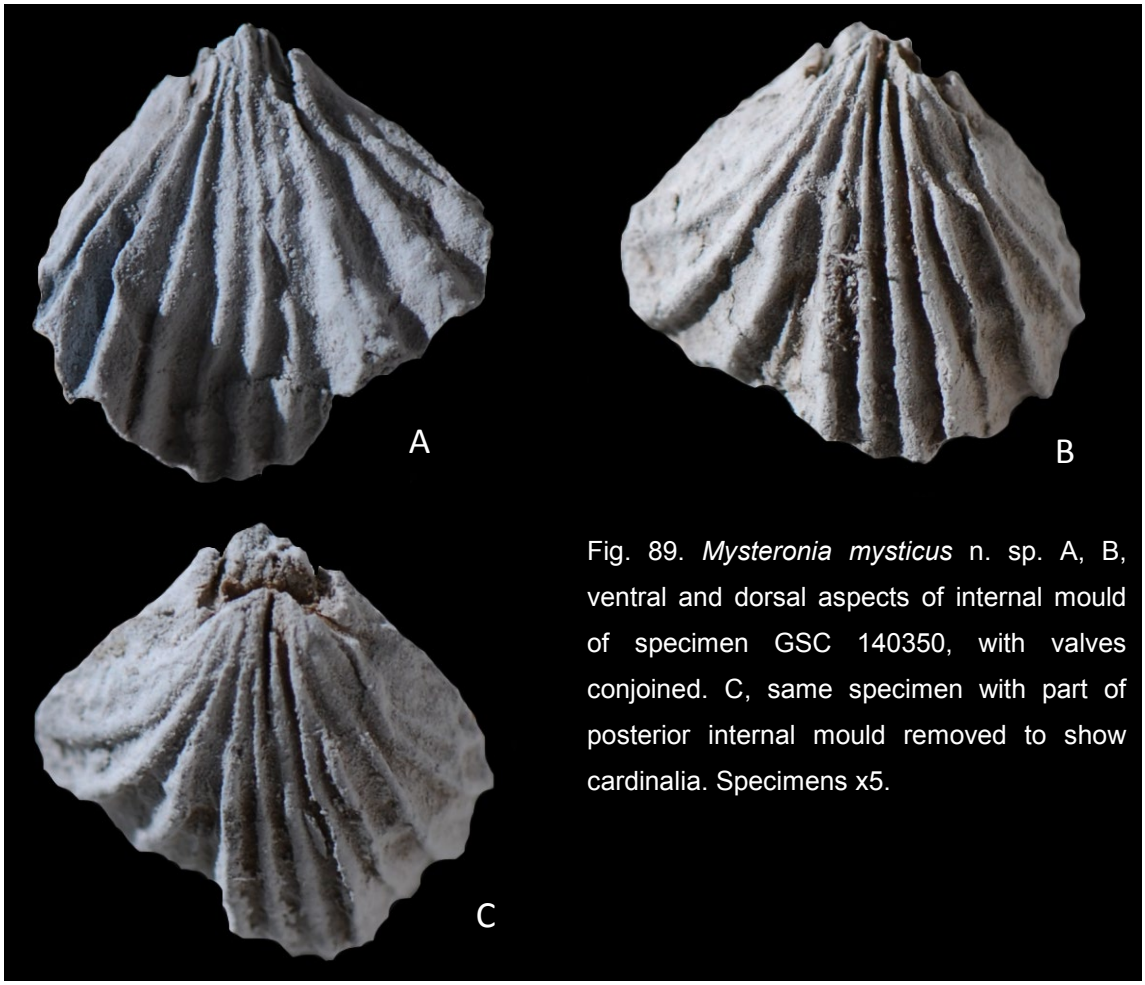


Fig. 89. *Mysteronia mysticus* n. sp. A, B, ventral and dorsal aspects of internal mould of specimen GSC 140350, with valves conjoined. C, same specimen with part of posterior internal mould removed to show cardinalia. Specimens x5.

interspaces evenly curved. Micro-ornament involves well-spaced growth laminae and suggestions of radial lira.

Dental plates are sturdy, not very long, and extend along the interspace one or two

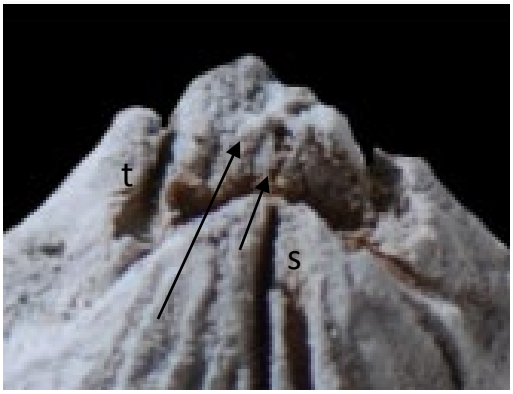


Fig. 90. *Mysteronia mysticus* n. sp. Enlargement of Fig. 89C, showing cardinalia, with removal of underlying matrix, GSC 140350. t = dental plate and tooth; s = dorsal median septum. Long arrow points to cardinal plate. Short arrow points to a shallow septalium with median ridge. Specimen x10.

Fig. 91. *Mysteronia mysticus* n. sp., ventral and dorsal external mould GSC 140351 with ventral umbonal region, showing mould of concave plate below the high delthyrium, holotype, x5.

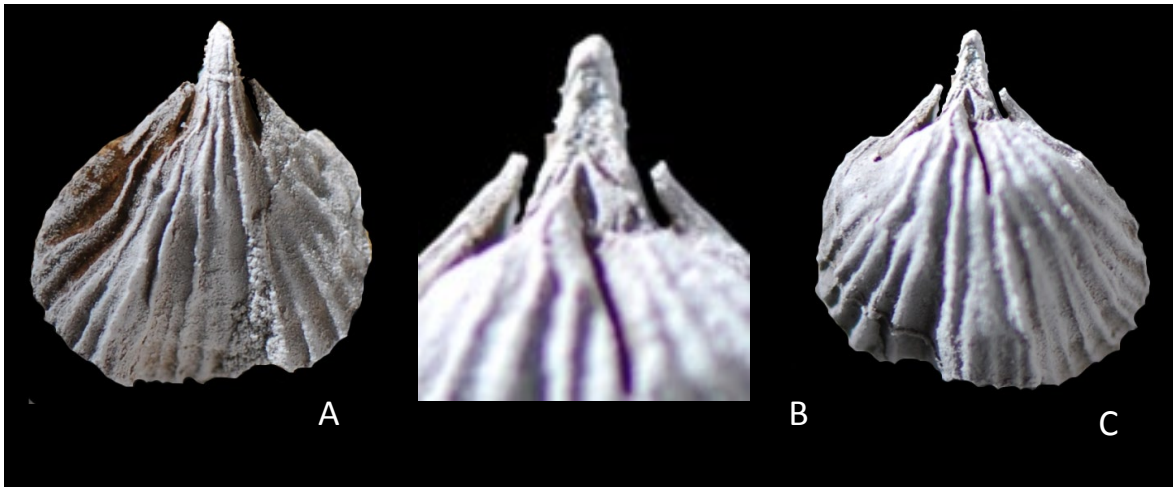


Fig. 92. *Mysteronia mysticus* n. sp. A – C, ventral and dorsal aspects of internal mould of specimen with valves conjoined as in Fig. 91, holotype GSC 140351. Note matrix-filled punctae developed over the umbonal region, in 92B. Fig. 92A, C, x5, 92B x10 approx.

removed from the sulcus, there being some variability and asymmetry. No ventral muscle scars can be discerned.

In the dorsal valve, a stout median septum extends over the posterior third of the shell length, and supports a broad cardinal plate that bears a gentle median depression in the larger of the two specimens with valves conjoined, and a wider median depression and narrow lateral cardinal plate in the other specimen, traversed longitudinally by a well defined median ridge.

Socket plates lie each side, without crenulations. No specimen shows any trace of muscle scars or cardinal process. Punctae penetrate much of the shell, and are visible over the internal and external moulds, suggesting that the exolayer of shell is very thin.

Resemblances: The Canadian form appears distinctive in shape and costation. There are a number of northern hemisphere species that externally show some approach in having strong ribs, but their interior is poorly known, or obscure, and so cannot be accurately compared. *Rhynchopora palumbula* Cooper & Grant (1976, pl. 696, fig. 1-43, pl. 697, fig. 1-5), chiefly from the Word Formation, and from beds between the Word and Appel Ranch Member (which is considered to be early Capitanian), has a ridge in the cover plate of most specimens, but the anterior shell is steep and high in mature specimens, and several indicate the presence of septalium underneath the cover plate. In most specimens the costae do not branch, although that figured in Cooper & Grant (1976, pl. 696, fig. 41) is exceptional in this regard.

Superorder ATRYPIFORMI Moore, 1952

Order ATHYRIDA Boucot Johnson & Staton, 1964

Superfamily **ATHYROIDEA** Davidson, 1881

Subfamily **CLEIOTHYRIDININAE** Alvarez, Rong & Boucot, 1998

Genus ***Deltachania*** Waterhouse, 1971

Diagnosis: Distinguished by absence of cardinal plate between the dental socket plates of dorsal valve.

Type species: *Deltachania acanthatia* Waterhouse, 1971, p. 217 from equivalents of lower Ettrain Formation, Yukon Territory, OD.

Discussion: The shape of the shell is more subpentagonal than the oval outline of *Cleiothyridina*.

Deltachania elongata n. sp.

Fig. 93, 94

Derivation: elongate – modification of longe – distant, Lat.

Diagnosis: Elongate subpentagonal shells. Dorsal septum low or scarcely developed.

Holotype: Specimen GSC 140353 illustrated in Fig. 93D-G, here designated.

Material: Three specimens with valves conjoined, and seven ventral valves.

Dimensions in mm: both valves

Width	Length	Height	Hinge width
28	23	23	20
31	25	16	21

Description: Shells weakly transverse and moderately inflated, with a moderately wide hinge and obtuse cardinal extremities. The foramen is small and mesothyrid, and the posterior walls diverge at 90^{o} in one specimen before curving along the hinge, whereas in the other large specimen with valves conjoined, the ventral umbo is broader, with angle measuring 110^{o}, and the umbonal walls pass from the pedicle directly along the hinge. The dorsal umbo projects more, and infills the delthyrium. The ventral sulcus commences a little in front of the umbonal tip and is well defined, with angle of 10^{o} in the more transverse specimen and 15^{o} in the other more inflated shell, measured from the umbonal tip, and the floor is evenly concave. The dorsal valve has a low median raised fold, commencing a little in front of the umbo, and divided by a shallow narrow median groove. Commargons cover both valves, numerous and of varying width, with flat treads bearing fine pits, and separated by narrow grooves or lamellae. Only traces of irregular anterior margins suggest the presence of spines, which if present must have been small and fine, but seemingly larger than the athyrid micro-frills described by Alvarez et. (1987). But reservations must be retained about the spines, which affects the subfamily classification for this material.

Dental plates represented by short plates close to the posterior wall. Adductor ridges are narrow and flanked each by a large and impressed diductor scar covered by fine pustules, and the posterior lateral floor of the shell bears elongate shallow pits. In the dorsal valve, a low median ridge is present in one specimen, but the median septum is not well formed. The other and leached specimen shows a low short adductor ridge and no median septum. The cardinal process area bears narrow closely spaced vertical laminae. Socket plates rest on the floor of the valve, with sockets broadening each side. There is no cardinal plate, judged by the leaching of a specimen and preparation of the shell.

Resemblances: This species resembles *Deltachania acanthatia* Waterhouse in subpentagonal

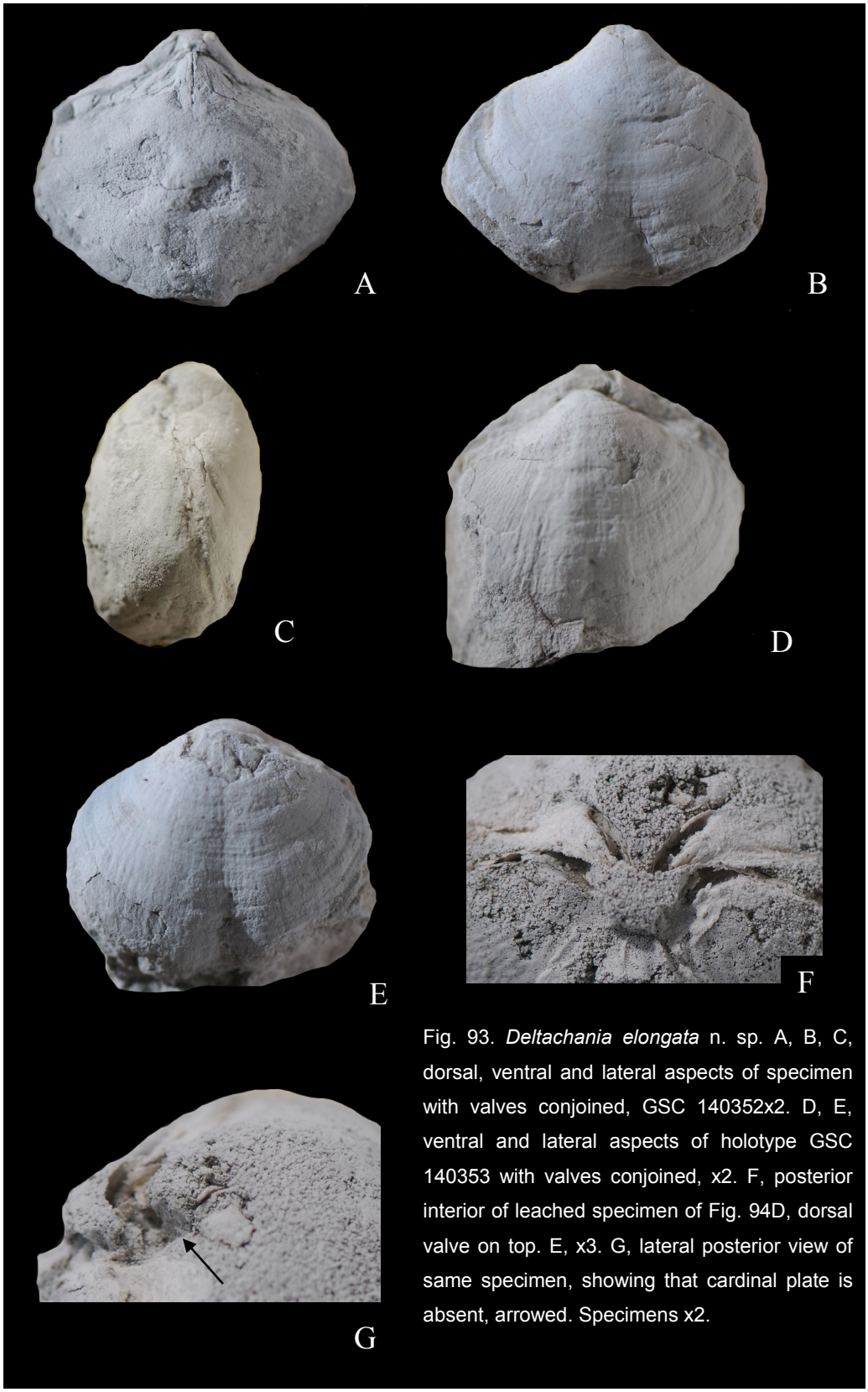


Fig. 93. *Deltachania elongata* n. sp. A, B, C, dorsal, ventral and lateral aspects of specimen with valves conjoined, GSC 140352x2. D, E, ventral and lateral aspects of holotype GSC 140353 with valves conjoined, x2. F, posterior interior of leached specimen of Fig. 94D, dorsal valve on top. E, x3. G, lateral posterior view of same specimen, showing that cardinal plate is absent, arrowed. Specimens x2.

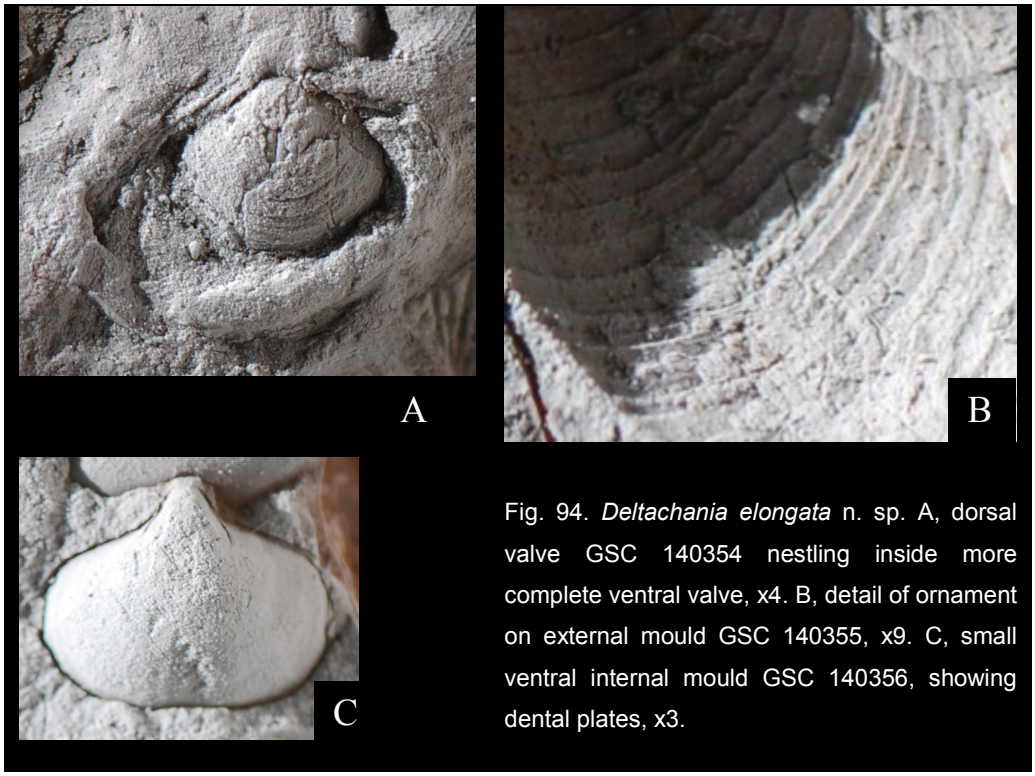


Fig. 94. *Deltachania elongata* n. sp. A, dorsal valve GSC 140354 nestling inside more complete ventral valve, x4. B, detail of ornament on external mould GSC 140355, x9. C, small ventral internal mould GSC 140356, showing dental plates, x3.

subpentagonal shape and size, but the present material has a more elongate shell with a better defined ventral sulcus and more raised and longer dorsal fold, which bears a shallow median groove, and finer lower median dorsal septum in one specimen, and no septum visible in the holotype. Type *Deltachania* is found in overlying beds of the Ettrain equivalents exposed along the shores of the Peel River. It has fine flattened spines along the anterior margin of the commargons, and the dorsal valve has a sturdy median septum. *Deltachania* was severely misrepresented by Alvarez & Rong (2002), who expressed skepticism, Their skepticism seems to have been ill-founded, because the dorsal cardinalia was figured in Waterhouse (1971, pl. 26, fig. 8) to show the absence of a cardinal plate, and Waterhouse & Chen (2007, text-fig. 5) provided serial sections to further confirm the absence. That has also been determined for the present species, from careful leaching in dilute hydrochloric acid. But the spiralium and jugum remain unknown, inviting examination by a non-intrusive methology.

Species described in Abramov & Grigorieva (1983) from Verchoyan might prove to

belong to *Deltachania*. The species described as *Cleiothyridina pseudobajkurica* Abramov & Grigorieva (1983, p. 116, pl. 17, fig. 5-9, Fig. 40) displays a somewhat subpentagonal outline with swollen dorsal valve raised medianly, and the sections through the shell suggest that there was no cardinal plate. It comes from the Davnin and Ekachan levels of Upper Carboniferous age. *C. florenskayae* Abramov & Grigorieva (1983, p. 117, pl. 16, fig. 2, 3, Fig. 41) from the Davnin Horizon is more elongate and somewhat rounded in some aspects, again with subdued median dorsal fold, and sections suggest the absence of a median dorsal cardinal plate.

Superorder SPIRIFERIFORMI Waagen, 1883

Order SPIRIFERIDA Waagen, 1883

Suborder MARTINIIDINA Waterhouse, 2010

Infrasuborder MARTINIIMORPHI Waterhouse, 2010

Superfamily **MARTINIOIDEA** Waagen, 1883

Family **MARTINIIDAE** Waagen, 1883

Subfamily **MARTINIINAE** Waagen, 1883

Genus ***Papulifera*** n. gen.

Derivation: papula – pustule, fero – to bear, carry, Lat.

Diagnosis: Transverse as a rule with low anterior dorsal ribs and both valves covered by fine pustules. Dental plates absent, teeth short.

Type species: *Papulifera plana* n. gen., n. sp. from the Blackie Formation (Bashkirian) of Yukon Territory, here designated.

Discussion: The present material differs from *Martinia* M'Coy and other genera in the presence of low anterior costae, especially over the dorsal valve, and micro-ornament of fine dense pustules. It cannot be securely matched with any other genus. Dental plates are absent, and crural plates short.

Papulifera plana n. sp.

Fig. 95 - 99

Derivation: plane – plain, simple, Lat.

Diagnosis: Ventral valve transverse and swollen with deep anterior sulcus, dorsal valve comparatively flat. Low narrow ribs anteriorly, and micro-ornament of fine dense pustules.

Holotype: Specimen GSC 140357 figured in Fig. 95A & B, 96, 98, 99, here designated.

Material: Eight specimens with valves conjoined, two ventral valves, and fragments.

Dimensions in mm: both valves

Width	Length	Height	Umbonal angle	
39	33	26	95°	holotype
33	26	24	100°	internal mould

Description: Transverse shells, with ventral umbo incurved over well developed but low interarea, slightly narrower than the maximum width of the shell, which lies close to mid-length. Within the interarea, the delthyrium has an angle of 20°. The dorsal valve is little inflated in the holotype, except anteriorly, measuring 11mm thick compared with the ventral thickness of 16mm. In the figured internal mould, the ventral valve is 17mm thick and the dorsal valve 12mm thick. The ventral sulcus commences 28mm in front of the beak in the holotype, and no sulcus is seen in a specimen 24mm long. Anteriorly the sulcus developed as a flat-floored depression up to a third of the width of the shell, and protrudes dorsally as a short tongue. In a larger specimen 66mm wide, the sulcus is well extended. Compared with the ventral sulcus, the dorsal fold commences much nearer the hinge, and has a wide gently convex crest. The ventral valve is largely smooth, but the lateral flanks of the dorsal valve each bear some four very low and round-crested costae with interspaces of comparable width and depth, not visible on the internal mould. The shell is crossed by low commarginal rugae, most clearly developed on the anterior part of the largest ventral valve, and over the dorsal valve, numbering seven on the holotype: theyhave probably having been exaggerated by compression. Micro-ornament consists of pustules, one set spaced almost 1mm apart along commarginal rows, and the other set much finer and denser than the other, possibly reflecting the ends of prisms in the shell, though this remains to be established.

The delthyrium is bordered by dental flanges, but there are no dental plates, and the muscle field is not impressed into the shell. There are low crural plates, but the remainder of the dorsal interior is poorly preserved and obscure, though the spire is visible laterally in one specimen, with nine coils.

Resemblances: There is some approach to *Martinia lata* Girty (1927, p. 417, pl. 24, fig. 1-7)

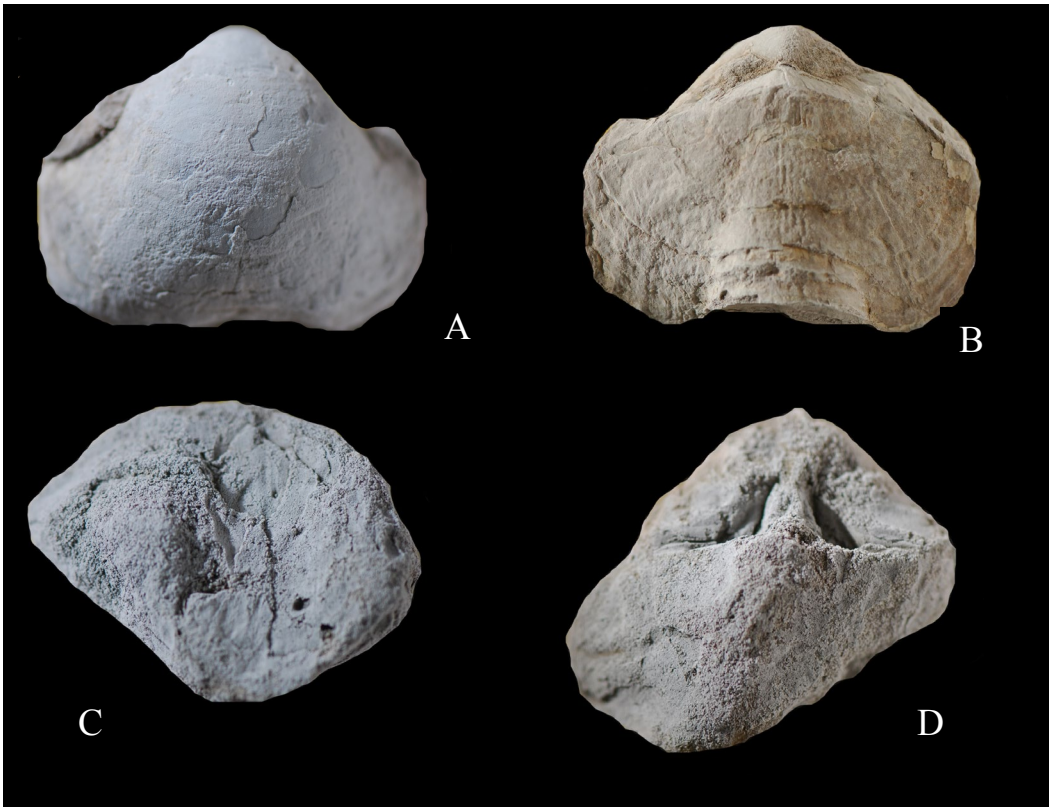


Fig. 95. *Papulifera plana* n. gen., n. sp. A, B, ventral and and dorsal aspects of holotype, specimen with valves conjoined, GSC 140357, bearing fine ribs over the fold and one flank, not seen in other shells. Also figured in Fig. 96, 98, 99. C, D, anterior ventral and dorsal aspects of internal mould of specimen with valves conjoined, GSC 140358. Specimens x1.5.

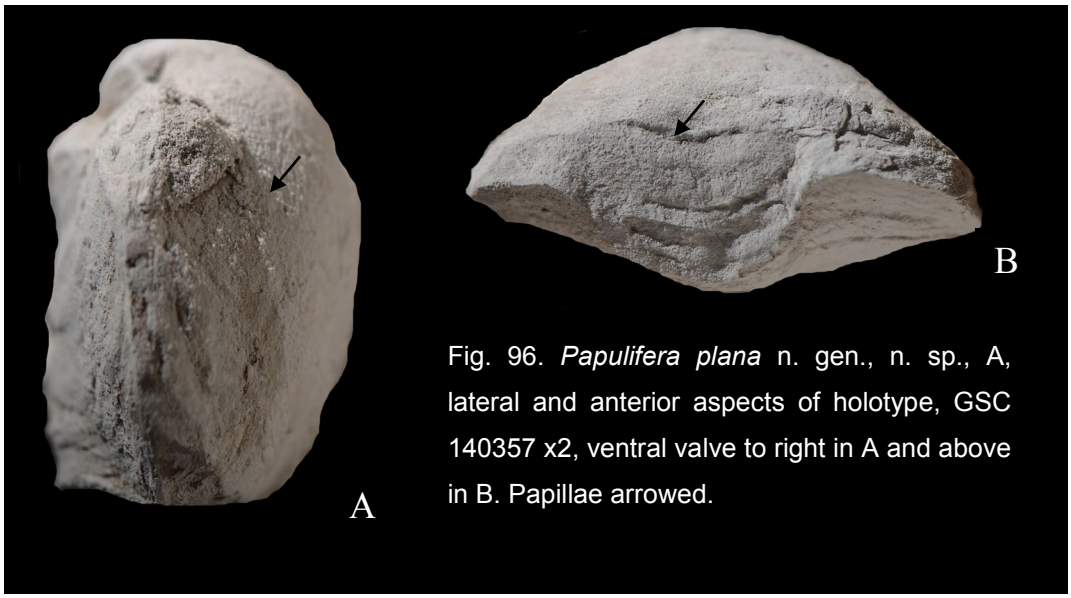


Fig. 96. *Papulifera plana* n. gen., n. sp., A, lateral and anterior aspects of holotype, GSC 140357 x2, ventral valve to right in A and above in B. Papillae arrowed.

Fig. 97. *Papulifera plana* n. gen., n. sp. A, ventral valve, GSC 140359. B, cast of ventral valve GSC 140360. Specimens x1.5.

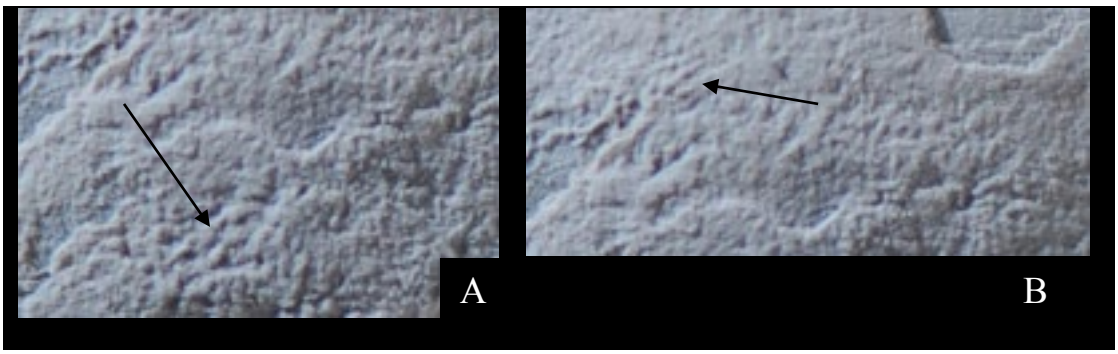


Fig. 98. *Papulifera plana* n. gen., n. sp. A, B, micro-ornament of minute pustules, arrowed, ventral aspects of holotype, GSC 140357 x8, The finer pustules could represent the ends of prisms within the shell

Fig. 99. *Papulifera plana* n. gen. n. sp., micro-ornament of pustules of two sizes and growth increments within the anterior sulcus of the holotype, GSC 140357 x10.

from the Brazer Limestone of Idaho, though specimens of Girty's species tend to be less transverse and the ventral sulcus is a narrow groove medianly and matches a dorsal median groove.

Martinia buckmani Yanischevsky in Aisenberg (1983, pl. 51, fig. 1a-c) is small but less transverse and with better defined sulcus. From the Bashkirian Karanelginsk Horizon of the Russian Platform and Suransk Horizon and Akavass Horizon of the Urals, *Martinia corpulenta* Semichatova (1969, p. 171, pl. 3, fig. 7; *in* Stepanov et al. 1975, p. 200, pl. 92, fig. 4) is somewhat similar in shape, but lacks the anterior well defined sulcus of the Canadian form. None of these specimens are known to have a micro-ornament of fine pustules, which are not reported to occur in any other related martiniin genus, as summarized in Waterhouse (2016, pp. 89-94). Upper Carboniferous specimens described as *Martinia* (*Pseudomartinia*) *juresanensis* Stepanov (1948, p. 46, pl. 12, fig. 1-6) include one specimen that is similarly transverse with anterior sulcus, bearing more concave floor. Other specimens are more elongate. An Asselian specimen illustrated by Mironova (1967, p. 48, pl. 5, fig. 8a-c) is also close but displays a more developed anterior sulcus.

From Early Carboniferous faunas of Fife, Scotland, *Martinia? anceps* Reed (1948, p. 464, pl. 12, fig. 1-5) and "variety" *M*? *anceps semisulcata* Reed (1948, p 466, pl. 12, fig. 6) is transverse with only gentle sulcus and very low fold anteriorly. The ventral umbo is massive, and some specimens may show anterior costae. Micro-ornament involves commarginal and radial lira.

Suborder **SPIRIFERIDINA** Waagen, 1883

Superfamily **SPIRIFEROIDEA** King, 1846

Family **SPIRIFERIDAE** King, 1846

Subfamily **SPIRIFERINAE** King, 1846

Tribe **DONISPIRIFERINI** Waterhouse, 2016

Genus ***Saltospirifer*** Cisterna & Archbold, 2007

Diagnosis: Medium size, steep ventral posterior walls diverging forwards, ornament of a number of fascicles with moderately strong costae, wide sulcus. Connector plate.

Type species: *Saltospirifer guevarii* Cisterna & Archbold, 2007, p. 8 from the lower Del Salto

Formation (Pennsylvanian), Argentina, OD.

Discussion: This genus, though treated as a member of Neospiriferinae Waterhouse by its authors, is regarded as a member of Donispiriferini Waterhouse, 2016, because of its numerous well developed fascicles, each as a rule with one bifurcate pair of costae, unlike the few well developed and multicostate plicae typical of Neospiriferinae Waterhouse, 1968b. The sulcus is well developed, and a connector plate is developed in the ventral valve between the dental and adminicular plates (Cisterna & Archbold 2007, Fig. 6), just as in Donispiriferini, whereas members of Neospiriferinae lack a connector plate, and have an arched delthyrial cover plate, possibly modified from a stegidium. The genus *Saltospirifer* may be distinguished from *Donispirifer* by its less widely diverging and moderately steep posterior walls, imparting a peculiar hunched appearance in the ventral valve, in which the ventral umbo is strongly incurved, and the posterior walls are relatively high and steep. A few other spiriferoid genera show something of the same attribute, and have accordingly been distinguished, but they belong mostly to other families, tribes or lineages within the superfamily. One of the closest is *Crassispirifer* Archbold & Thomas, 1985 from the Permian of Western Australia, and this is a member of Spiriferidae within subfamily Fusispiriferinae Waterhouse, 2004, 2013, p. 193, named for highly transverse shells with well developed plicae, and posterior wall much lower than that of *Saltospirifer. Pondospirifer* Waterhouse, 1978 from the Late Permian of Nepal has steep but lower posterior walls, and wide hinge extended laterally rather than forwards, and broad few plicae, and lacks a connector plate. It is a member of Neospiriferidae Waterhouse.

Cisterna & Archbold (2007) claimed that *Saltospirifer* was of Sakmarian (Early Permian) age, but associated brachiopods, palynomorphs and radiometric evidence point to a Late Carboniferous age, as summarized in Waterhouse (2016, p. 172). They also reported the genus in the very early Permian of Western Australia, but this is yet to be substantiated.

The genus is regarded as a member of Donispiriferini. *Donispirifer* itself, as named by Poletaev (2000) and described from mostly Moscovian faunas of Ukraine, is of small to medium size, with comparable fascicles, more widely extended posterior walls, and narrow sulcus. Another member of the subfamily, *Pristinusia* Waterhouse, 2016 from the Bashkirian-?Moscovian faunas of Queensland, has similar hinge, low posterior walls, well defined narrow sulcus and fold, coarse costae, and weakly defined fascicles. Members of the tribe are indeed

close to genera placed within Spiriferini, in having a number of fascicles, and differ in being somewhat smaller than genera within Spiriferini, and limited to a Pennsylvanian age. Further attributes of Donispiriferini are discussed in Waterhouse (2016, p. 171ff).

Saltospirifer gibberosus n. sp.

Fig. 100, 101

Derivation: gibberosus – hunch-backed, Lat.

Diagnosis: Medium-large size for the tribe, inflated, strongly incurved ventral umbo, posterior walls diverge forward, sulcus wide and shallow, fold wide anteriorly, fascicles numerous and costae of moderate strength.

Holotype: Specimen GSC 140366 figured in Fig. 101A, B, here designated.

Material: Nineteen ventral valves and eleven dorsal valves, variously incomplete, with fragments.

Dimension in mm: ventral valves

Width	Length	Height	Umbonal angle	Sulcal angle	Cardinal angle
60	45	31	110°	40°	85°
54	45	30	110°	40°	135°

Description: Shells transverse with broad moderately incurved umbones, moderately high interarea bearing delthyrium, and hinge a little less than maximum width, which lies near the anterior third of the shell length. The posterior walls diverge forward at 130° to 140°, compared with divergence of 160° to 180° in other genera of the tribe. Cardinal extremities are slightly variable, and show either very small bluntly acute ears, or are broadly obtuse. The sulcus commences at the umbo, and is broad with narrow median gutter, each flank being gently convex, and extends to the anterior margin with increasing width and depth. The dorsal valve has a low interarea, and a number of specimens have tiny ears. The fold commences at the umbo and increases steadily in height and width to the anterior margin. Its crest is narrowly arched, and flanks are gently convex. Both valves are ornamented by narrow fascicles, nine pairs each side of the sulcus, commencing at or just in front of the beak, and in a short distance two pairs enter the sulcus in front, followed anteriorly by two further pairs. These remain strong, but the outer two pairs of fascicles are very low and narrow. Two pairs divided by a prominent groove develop on the dorsal fold, which is more constrained in width

than the sulcus. The ventral fascicles bear several costae, usually two or sometimes more towards the centre but only one laterally, without a regular reduction outwards in number. The inner pair has two costae, the adjoining pair four costae, both within the sulcus, and a median costa traverses the sulcus in some specimens, a groove in others. Over the fold, the innermost fascicle is narrow with two costae, and the adjoining fascicle is wider with four costae. The fascicle pair next to the fold divides into two anteriorly, and costae commence within 13mm of the hinge. The next two pairs of fascicles become costate, and outer fascicles have only one costa. Overall they are better defined than those of the ventral valve. Micro-ornament consists of fine growth increments, and only traces of very faint fine radial fila, best

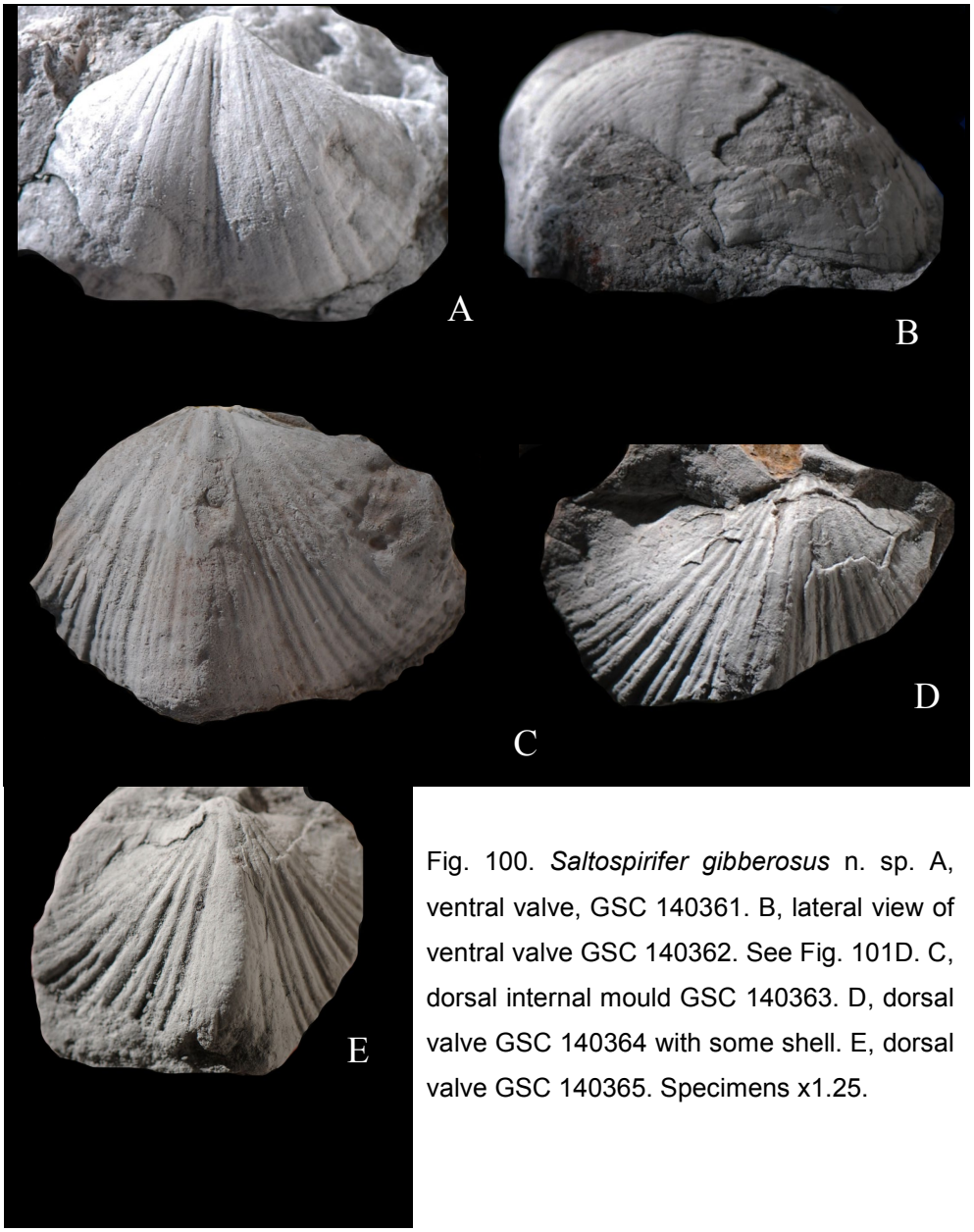


Fig. 100. *Saltospirifer gibberosus* n. sp. A, ventral valve, GSC 140361. B, lateral view of ventral valve GSC 140362. See Fig. 101D. C, dorsal internal mould GSC 140363. D, dorsal valve GSC 140364 with some shell. E, dorsal valve GSC 140365. Specimens x1.25.

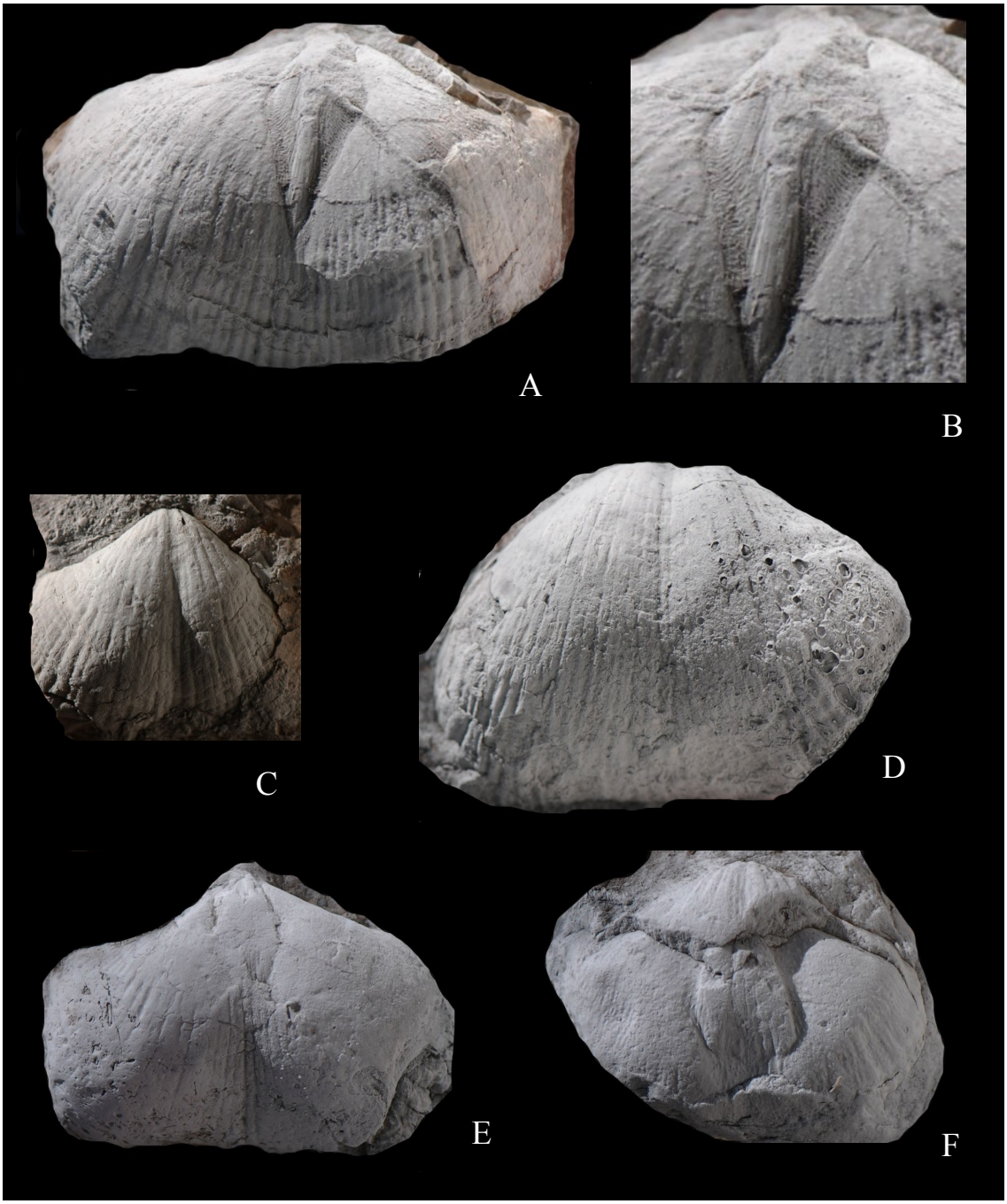


Fig. 101. *Saltospirifer gibberosus* n. sp. A, B, ventral valve holotype GSC 140366 showing muscle field. B, detail of adductor field, x3. C, ventral valve GSC 140367. D, ventral valve GSC 140362. See Fig. 100B. E, ventral valve GSC 140368, showing adductor field. F, ventral valve interior with shell posteriorly, GSC 140369. Specimens x1.5, except 101B, x3.

preserved along the middle of the interspaces, and numbering about eight to ten in 1mm.

The ventral muscle field is comparatively small, with narrow adductor scars, placed in a shallow trough, and bordered by broader obliquely ridged diductor scars (Fig. 101B).

Adminicula extend along side for the posterior half to two thirds of the length of the muscle field, in front of which the two sides of the muscle field converge. These support dental plates, and are possibly spanned by a connector plate, but not this is not definite, thanks to poor preservation. The dorsal interior lacks tabellae, but further detail is not exposed.

Resemblances: Important aspects of the internal morphology are concealed, but the overall shape and general appearance strongly suggests that the genus and species belong to Donispiriferini thanks to the high number of narrow fascicles and general shape, and the strong longitudinal curvature, divergent posterior ventral walls, very wide ventral sulcus and high narrow-crested fold indicate an alliance with *Saltospirifer* from Argentina. *S. guevarii* Cisterna & Archbold (2007, Fig. 4A-O, Fig. 5, 6) has slightly less massive ventral posterior walls, a sulcus that is more U-shaped in profile, a wide but less narrowly-crested dorsal fold, and shared occurrence of bifurcate costae. The age is likely to be close to Moscovian, with radiometric and fossil support (Césari et al. 2011; Waterhouse 2015, pp. 41, 42), rather than early Permian as supposed by Cisterna & Archbold (2007).

The type species of *Donispirifer*, *D. baschkovensis* (Rotai, 1951) from the Moscovian of the Donets Basin in the Ukraine, has more widely diverging posterior walls and maximum width is placed more posteriorly (see also Poletaev 2000, pl. 6, fig. 1, 2, 5, text-fig. 1), and *D. toretzensis* Poletaev (2000, pl. 6, fig. 3, 4), another Moscovian species from the Donets Basin, is rather similar in outline, but larger, with large flat-crested costae next to the sulcus increasing by branching.

A Desmoinesian species from New Mexico, here tentatively transferred to *Donispirifer, Neospirifer tewaensis* Sutherland & Harlow (1973, p. 74, pl. 15, fig. 9-11), is more elongate with more prominent sulcus. None of the other species of Bashkirian or Moscovian age that were also referred to *Donispirifer* by Poletaev (2000) seem particularly close to the present species.

The Yukon specimens are moderately similar to the species named *Neospirifer tomskiensis* Benediktova (1956, p. 179, pl. 11, fig. 7, 8, 10, 11, pl. 3, fig. 1-3, 6) from west Siberia, also recorded from the Middle Carboniferous Tutchaltuisk Suite of west Zabaikal by Kotlyar & Popeko (1967, p. 154, pl. 43, fig. 1-6), but present specimens are more swollen and elongated, with slightly wider sulcus anteriorly, and consistently less widely diverging

posterior ventral walls.

Subfamily **SPIRIFERALARIINAE** Waterhouse, 2016

Diagnosis: Distinguished by well developed and costate plicae. Connector plate present.

Name genus: *Spiriferalaria* Waterhouse, 2002a, p. 231 from Guadalupian of Texas.

Genus ***Tegulispirifer*** Poletaev, 2000

Diagnosis: Medium-sized to large transverse shells with extended hinge and well developed costate plicae, micro-ornament often with strong commarginal laminae where well preserved, and fine radial capillae. Stegidial cover, small umbonal callosity and connector plate.

Type species: *Spirifer tegulatus* Trautschold, 1876, p. 354 from Moscovian (Middle Pennsylvanian) of Moscow Basin, Russia, OD.

Discussion: *Tegulispirifer* Poletaev is close to *Spiriferalaria* Waterhouse, sharing the strongly plicate and closely costate exterior, with a connector plate across the delthyrium, but it lacks the exaggeratedly alate extremities of *Spiriferalaria*.

Tegulispirifer sp.

Fig. 102, 103

Material: Four ventral valves.

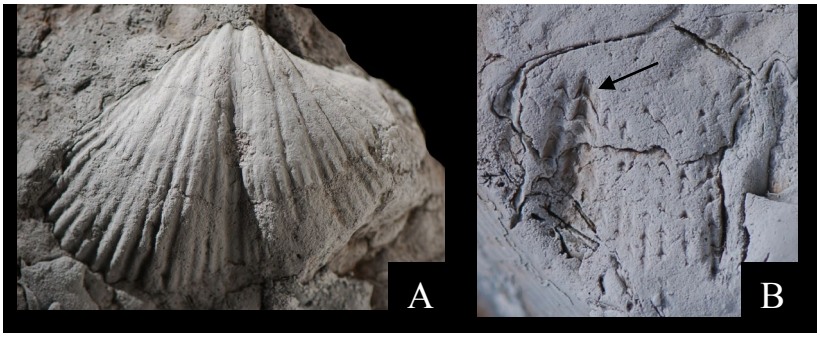


Fig. 102. *Tegulispirifer* sp. A, ventral valve GSC 140370 x2. B, external fragment of external ventral mould GSC 140371, showing tegulate growth lamellae as arrowed, x3.

Description: The shells have few and coarse costae numbering three close to the sulcus on low but well defined plicae in four to five pairs. One external and internal mould shows a

gently convex connector plate between the dental plates and adminicula. A dorsal valve measures 66mm in width and 34mm long, with fold that broadens anteriorly, and shows a low median septum. The specimens are moderately close in age to that of type *Tegulispirifer* Poletaev, 2000, and appear to belong to that genus. This is supported by a fragment of an external ventral valve, which shows well developed growth lamellae, typical of the type species of *Tegulispirifer* (Fig. 102B).

Fig. 103. *Tegulispirifer* sp. A, dorsal valve GSC 140372. B, ventral valve GSC 140373. C, ventral internal mould GSC 140374. Specimens x1.5.

Superfamily **SPIRIFERELLOIDEA** Waterhouse, 1968b

Family **SPIRIFERELLIDAE** Waterhouse, 1968b

Subfamily **SPIRIFERELLINAE** Waterhouse, 1968b

Genus ***Spiriferella*** Tschernyschew, 1902

Diagnosis: Elongate, strongly plicate and variably costate, with cancellate and pustulose micro-ornament and well developed plicae separated by narrow interspaces. Dorsal fold traversed by narrow and shallow median groove for its full length.

Type species: *Spirifer saranae* de Verneuil, 1845, p. 169 from near Krasnoufimsk (Artinskian) in the Urals of Russia, OD.

Discussion: The fold is particularly distinctive.

Spiriferella primaeva Waterhouse & Waddington, 1982

Fig. 104

1982 *Spiriferella primaeva* Waterhouse & Waddington, p. 12, pl. 1, fig. 1-6, text-fig. 10.

Diagnosis: Small shells, few plicae, broad incurved ventral umbo.

Holotype: GSC 35475 from lower Ettrain equivalents of Peel River, Yukon Territory, figured by Waterhouse & Waddington (1982, pl. 1, fig. 1, 2, 5), OD.

Material: Two ventral valves.

Description: The specimens are poorly preserved, and have massive incurved ventral umbo, well defined ventral sulcus, and three principal pairs of plicae.

Resemblances: The specimens are broken, incomplete and poorly preserved, but in their general appearance with three prominent pairs of plicae and two finer lateral pairs, they come close to *Spiriferella primaeva* as figured in Waterhouse & Waddington (1982) from lower Ettrain equivalents along the Peel River. The text in that study mentions a fourth pair of plicae, which is suggested in one of the present specimens, and a fifth pair of plicae or low costae, much as in the present specimen. Lack of dorsal valve and the preservation allows the identification to be no more than putative.

Fig. 104. *Spiriferella primaeva* Waterhouse & Waddington, ventral valve GSC 140375. Specimen x1.5.

Order **SPIRIFERINIDA** Ivanova, 1972

Suborder **SPIRIFERINIDINA** Ivanova, 1972

Superfamily **PENNOSPIRIFERINOIDEA** Dagys, 1972

Family **PARASPIRIFERIDAE** Cooper & Grant, 1976

Genus ***Zaissania*** Sokolskaya, 1968

Zaissania? sp.

Fig. 105

1971 *Zaissania* sp. Bamber & Waterhouse, p. 122, pl. 3, fig. 12, 14.

Material: Two ventral valves, one very incomplete.

Description: A ventral valve with four pairs of plicae and fine dense punctae shows closely spaced commargons, slightly pustular in places, perhaps due to the punctae, and fine radial lira with aligned pustules varying from two to four per mm in the plical interspaces. It measures 16mm wide and 15mm long, and is nearly 7mm high. The sulcus widens at an angle of 15°. Bamber & Waterhouse (1971) recorded *Zaissania* sp., figuring the internal mould of a ventral valve with large median septum, and an external mould showing micro-ornament, but these specimens are not available, and it is not clear that the small spines typical of *Zaissania* are developed in present material.

Fig. 105. *Zaissania*? sp., ventral valve GSC 140376, x6.

Family **SPIRIFERELLINIDAE** Ivanova, 1972

Spiriferellinid? gen. & sp. indet.

Fig. 106, 107

Material: One ventral valve.

Description: A ventral valve with five pair of plicae and fine dense punctae. It measures 25mm wide and 17mm long, and is 8mm high. The sulcus widens at angle of 25°, and bears an anterior median rib in the sulcus. The shell is penetrated by minute open evenly spaced punctae, within slightly protruding spinules. The apparent micro-ornament is close to that of

Spiriferellina Fredericks, 1924, which has regularly arranged spinules.

Fig. 106. Spiriferellinid? gen. & sp. indet., ventral valve GSC 140377 x5.

Fig. 107. Spiriferellinid? gen. & sp. indet., GSC 140377, showing dense open punctate pustules, x12. The whitening has covered the punctae.

Suborder SYRINGOTHYRIDINA Grunt, 2006

Superfamily **LICHAREWIOIDEA** Slusareva, 1958

Family **LICHAREWIIDAE** Slusareva, 1958

Name genus: *Licharewia* Einor, 1939, p. 69 from Kazanian (Middle Permian, approximately Wordian) of Russia, OD.

Diagnosis: Transverse shells with acute cardinal extremities, numerous plicae, and pustules and grooves. Shell taleolate rather than punctate. Internal plates of adminicula, dental plates,

connector plate and crural plates, with no ventral median septum or dorsal tabellae.

Discussion: Genera such as *Yukonospirifer* Shi & Waterhouse, *Nahoniella* Shi, 1998 and apparently *Tumarinia* Grigorieva & Solomina, 1973, at least as judged from Yukon material (see Waterhouse 2018, p. 395), are like the transverse and plicate genera *Licharewia* Einor, *Permospirifer* Kulikov and allies in being, as shown by examination of topotype and type material, taleolate rather than punctate (Waterhouse 2018, pp. 393, 394). Compared with Licharewia and *Permospirifer*, they tend to be more transverse, with more extended cardinal extremities that are alate as a rule, and have more numerous plicae, with less protruding antero-lateral margins.

Genus ***Yukonospirifer*** Shi & Waterhouse, 1996

Diagnosis: Transverse shells with numerous plicae, fold and sulcus costate.

Type species: *Yukonospirifer yukonensis* Shi & Waterhouse, 1996, p. 123 from the "*Yakovlevia transversa*" Zone (Sakmarian), Jungle Creek Formation, OD.

Yukonospirifer sp.

Fig. 108

Material: One ventral valve.

Description: Only the posterior part of the valve is preserved. It is transverse, at 98mm across, with maximum width along the hinge, a broad umbo and well defined narrow sulcus with angle of 15°. Plicae are slender and numerous, possibly as many as twenty each side of the sulcus, and anteriorly a few inner plicae split into two. Within the sulcus two costae branch from the plication that borders the sulcus close to the umbonal tip, and two further costae arise in front, as well as a median costa commencing seven mm in front of the umbonal tip.

Fig. 108. *Yukonospirifer* sp., ventral valve GSC 140378 x2.

Resemblances: Lateral plicae are more subdivided, and sulcal costae are much more numerous in *Yukonospirifer yukonensis* Shi & Waterhouse, 1996. The same was probably true of *Yukonospirifer* sp, which is represented by a dorsal valve with numerous costae over the fold, from the basal Jungle Creek Formation of Gzhelian age (Waterhouse 2018, p. 399).

Genus ***Tumarinia*** Grigorieva & Solomina, 1973

Diagnosis: Well developed delthyrial plate and long adminicula. Micro-ornament of pustules and grooves. Slightly rugose stegidium may be in contact with delthyrial plate. No calcite rod in umbonal cavity.

Type species: *Tumarinia orientalis* Grigorieva in Grigorieva & Solomina 1973, p. 36 from Omolon Horizon (Kazanian) of northeast Russia.

Tumarinia? sp.

Fig. 109

Material, Description: Part of a dorsal valve has low broad fold and low broad plicae, with traces of the micro-ornament and shell structure found in *Tumarinia* and species assigned to that genus from the Jungle Creek Formation (Shi & Waterhouse 1996, p. 125; Waterhouse 2018, p. 305).

Fig. 109. *Tumarinia* sp., external mould of dorsal valve GSC 140379, x2.

Superorder TEREBRATULIFORMI Waagen, 1883

Order TEREBRATULIDA Waagen, 1883

Superfamily **DIELASMOIDEA** Schuchert, 1913

Dielasmoid gen. & sp. cf. A

Fig. 110A

Material, Description: A poorly exposed ventral valve 12mm wide and elongate in shape, with a very shallow median sulcus externally, internally bearing a narrow median ridge which is represented by a median groove in the internal mould.

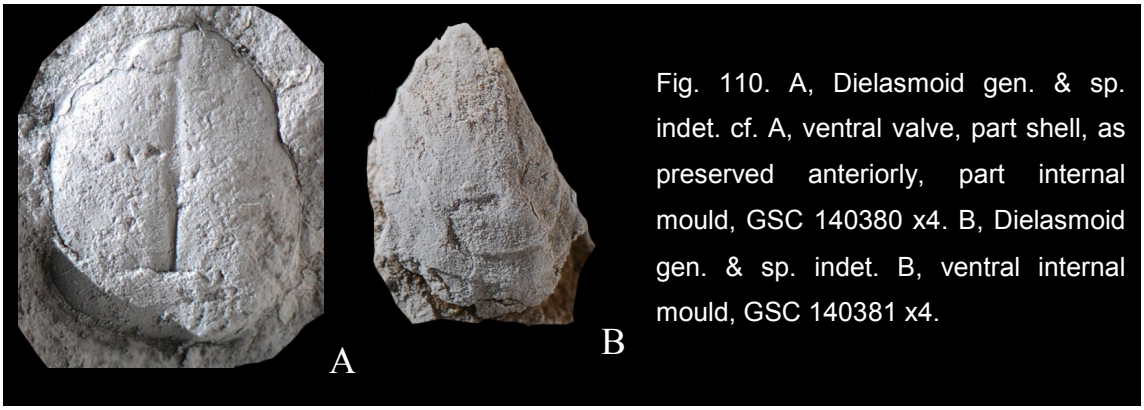


Fig. 110. A, Dielasmoid gen. & sp. indet. cf. A, ventral valve, part shell, as preserved anteriorly, part internal mould, GSC 140380 x4. B, Dielasmoid gen. & sp. indet. B, ventral internal mould, GSC 140381 x4.

Resemblances: The concave median venter and median groove on the internal mould recall features of the specimen from the Hart River Formation (see p. 64, Fig. 50).

Dielasmoid gen. & sp. B

Fig. 110B

Material, Description: A poorly exposed ventral valve 8mm wide and 11.5mm long with short dental plates. It has a swollen venter which lacks the shallow median sulcus bearing a median internal ridge that is present in the other specimen.

SUMMARY OF THE BRACHIOPOD FAUNA

This fauna is based on substantial collections by the writer from JBW 200 and 201. They were recorded in Bamber & Waterhouse (1971, p. 249) as occurring in section 116H-1B, at approximately 60ft and 290ft above the so-called top of Unit 2, but in fact within this unit, now referred to the Blackie Formation, as poorly exposed along the Peel River except at low water (Bamber & Waterhouse 1971, pp. 52, 57). The fossils from the two levels are largely similar but not exactly the same. From the lower level, JBW 200, come the following species:

Orbiculoidea sp. B, Streptorhynchin gen. & sp. indet. A, *Fimbrininia*? sp., *Onopordumaria punctura* Waterhouse, *Buxtonia sulcata* n. sp., *Umboanctus spinosus* Waterhouse, *Calliprotonia* sp., Echinalosiin gen. & sp. indet. A, Megousiin? gen. & sp. indet., *Muirwoodiciana inexpectans* n. gen., n. sp., Linoproductid gen. & sp. indet., *Praeschrenkiella*? sp. indet., *Ovatia*? sp., Cancrinellinin gen. & sp. indet., *Deltachania elongata* n. sp., *Papulifera plana* n. gen., n. sp., *Saltospirifer gibberosus* n. sp., *Tegulispirifer* sp., *Spiriferella primaeva* Waterhouse & Waddington, Spiriferellinid? gen. & sp. indet., *Yukonospirifer* sp., *Tumarinia*? sp., and Dielasmoid gen. & sp. indet. cf. A. From the upper level, JBW 201, come the following species: Streptorhynchin gen. & sp. indet. A, *Kiangsiella* sp., Chonetoid gen. & sp. indet., *Tuberculatella* sp., *Bailliena nudymensis* Sarytcheva, *Onopordumaria punctura* Waterhouse, *Buxtonia sulcata* n. sp., *Umboanctus spinosus* Waterhouse, Echinalosiin gen. & sp. indet. A, *Levipustula canadensis* n. sp., *Mysteronia mysticus* n. gen., n. sp., possible fragments *of Deltachania elongata* n. sp., *Papulifera plana* n. gen., n. sp., *Saltospirifer gibberosus* n. sp., *Tegulispirifer* sp., *Zaissania*? sp., and Dielasmoid gen. & sp. indet. B

Similar collections were made from the north bank of the Peel River, at localities GSC 53732 and 53733 (see Bamber 1972, p. 102; Waterhouse 1968d, pp. 5, 10). Fossils from this band were illustrated in Bamber & Waterhouse (1971, pl. 3, fig. 10-14), and included some of the present species, including *Zaissania*, *Onopordumaria* and *Umboanctus*, for which type material is housed at the Geological Survey of Canada in Ottawa. Mention was also made of *Choristites* with broad ribs (Bamber & Waterhouse 1971, p. 125), but only a fragment of this genus is found in the present collections.

Preliminary faunal lists were compiled for macro-fossils from this zone from the Nahoni Range, at section 116G-5 by Waterhouse (1968c, pp. 25-33) and at Whitestone River for section 116G-9B in Waterhouse (1968c, pp. 35-40), Cathedral Rocks for section 116J-41 in Waterhouse (1968c, p. 45), and Peel River section 116H-1A in Waterhouse (1968d, p. 5) and section 116H-1B in Waterhouse (1968d, p. 10, with possible further data on pp. 11, 13).

CORRELATION AND AFFINITIES

The fossils came from what was described in Bamber & Waterhouse (1971) as lower Ettrain equivalents, later amended to Unit 2, and now treated as Blackie Formation of Pugh (1983)

by Bamber in Bamber et al. (1989). Foraminifera from locality C-2696, found a little above the brachiopods, were judged to belong to the "Makarov fauna", provisionally assigned to the Bashkirian Stage, by B. L. Mamet, and equivalent to upper Namurian (see Wagner & Winkler Prins 1991, Fig. 5). In the Cathedral Rocks Anticline at section 116J-4A, calcareous sandstone above beds with fossils of the *Buxtonia sulcata* Zone (Waterhouse 1968c, p. 45) and judged to lie at the top of Unit 2 was found to have foraminiferal zone 21, of late Bashkirian to early Moscovian age, and this contains brachiopods of a different zone, Bm, now called the *Rorespirifer prodigium* Zone, as described below. There are no known ammonoids or conodonts in the present fauna, and the brachiopods are not fully informative, because they are dominated by genera yet to be found elsewhere, such as *Onopordumaria, Umboanctus*, *Mysteronia* and *Papulifera*, and a rare northern hemisphere occurrence of *Saltospirifer,* as well as a unique species of *Buxtonia*. Associated species that are less common strongly suggest affinities with the Ettrain Formation and equivalents, and even the overlying Jungle Creek Formation. These include members of *Bailliena, Fimbrininia*?*, Praeschrenkiella, Spiriferella, Yukonospirifer* and *Nahoniella*. On the other hand, *Muirwoodiciana* suggests a link with the brachiopods from the Hart River Formation.

Overall the assemblage is interpreted as signifying a marked change in the fauna from Early Carboniferous faunas, to faunas of early Pennsylvanian age. The paucity of fossil localities in the Blackie Formation allows the presence of barren sediment equivalent or partly equivalent to Serpukhovian and possible Bashkirian age, with uncertainty prevalent. The preference for a Bashkirian age for the described fossils appears to be supported from evidence from the southern paleohemisphere, with Roberts (1981, 1985) favouring such an age for the *Levipustula levis* Zone, and Taboada (2010, p. 160) casting doubt on apparent evidence for a slightly greater age of Serpukhovian for Levipustulinae in the Argentine. The affinities of the brachiopods, with their implications of the introduction of genera and species that indicate cooling temperatures and distinctively high paleolatitudinal associations, strongly point to an early Pennsylvanian rather than upper Mississippian age.

***Buxtonia sulcata* biozone**

The fossils are referred to the *Buxtonia sulcata* Zone. This species is large and prominent. Two associated species, *Umboanctus spinosus* Waterhouse and *Saltospirifer gibberosus* n.

sp. are also prominent, and several genera suggest ties with the overlying *Rorespirifer prodigium* Zone, whereas the faunas are strongly distinguished from those of the underlying *Quadralosia delicata* Zone. The age is deemed to be Bashkirian (Alekseev et al. 2004; Heckel 2004, Fig. 1), possibly lower Bashkirian.

The zone differs significantly from the underlying *Quadralosia delicata* Zone, and may well be separated from that zone by a modest time interval, embracing for example the Serpukhovian level.

BRACHIOPODS FROM THE UPPER BLACKIE FORMATION AND WAHOO FORMATION, LISBURNE GROUP

Rorespirifer prodigium biozone

Lithologies and distribution

The Lisburne Group of Schrader (1902) and Bowsher & Dutro (1957) in Alaska was extended in Bamber & Waterhouse (1971) eastwards into the northern Yukon Territory and applied to a light to medium grey-weathering carbonate unit that commonly forms cliffs above the recessive dark grey Kayak Formation and below the brown and dark grey rocks of Permian and Triassic age (Bamber in Bamber & Waterhouse 1971, p. 79). The Wahoo Formation at the top of the group has been collected in the Barn Mountains and Malcolm River of the northwest Yukon Territory and is composed mainly of skeletal and skeletal micritic limestone, with silicified fossils that can be dissolved out from the calcareous matrix by leaching in dilute hydrochloric acid. Further south, comparable faunas have been found in the upper Blackie Formation of Pugh (1983), as replacing the name Unit 2 for beds in the northern Ogilvie Mountains, Nahoni Range and Cathedral Rocks, with lithologies summarized on p. 69, and similar species have been recorded by Bamber & Waterhouse (1971) in the light grey cliff-forming skeletal limestone of the lower Ettrain Formation in the same areas.

Only a limited amount is available of the samples studied in Bamber & Waterhouse (1971). The brachiopods match what was called the B faunas in that study.

SYSTEMATIC DESCRIPTIONS

Phylum Brachiopoda Duméril, 1806

Class Strophomenata Williams et al. 1996

Superorder STROPHOMENIFORMI Öpik, 1934

Order TRIPLESIIDAE Öpik, 1934

Suborder ORTHOTETIDINA Cooper & Grant, 1974

Discussion: Orthotetida, although treated as an order and ascribed to Waagen (1884) by Cooper & Grant (1974) and Williams & Brunton (2000), was credited to Cooper & Grant (1974) by Waterhouse (2010, 2018, p. 27), because ascription to Waagen (1884) was fictitious. Waagen had never proposed such an ordinal group. This renders Triplesiida Moore, 1952 as senior name for the ordinal group, and Orthotetidina was recognized as a component suborder of that group. Williams & Brunton (2000) placed orthotetids (s. l.) as a full order, separated from strophomenids by Productida. Up till their proposed classification, the orthotetids have always been regarded as close to and within Strophomenida Öpik, 1934 rather than Productida (Williams 1965), and despite differences, there are many morphological similarities which suggest that orthotetids diverged from within and remained within Strophomenida, as assessed by Manankov (1979). Williams & Brunton (1993, p. 932) provided a clear account of the prevailing classifications and possibilities at the time of writing, and it is considered that in consideration of their assessments, the overall relationship of orthotetids should be conveyed in classification, by classing them as a suborder in Superorder Strophomeniformi, which underlies the value of recognizing superorders.

Superfamily **ORTHOTETOIDEA** Waagen, 1884

Family **SCHUCHERTELLIDAE** Williams, 1953

Subfamily **STREPTORHYCHINAE** Stehli, 1954

Streptorhynchin gen. & sp. indet. B

Fig. 111

Material: Fragments of a dorsal valve and two ventral valves from GSC 53899, Wahoo Formation, Lisburne Group, at Malcolm River.

Description: Only fragments remain of this taxon. One shows the posterior part of a ventral valve, with well-formed convex pseudodeltidium, lacking a monticulus (see Waterhouse 2018, p. 31), and the interarea is marked by horizontal striae, but shows no sign of a perideltidum. The inner side of the delthyrium is bordered by very low rounded dental flanges, ending in blunt broad teeth. A dorsal fragment shows a large transverse cardinal process with four lobes seen in two pairs from a posterior aspect. These converge into two lobes at the commissure, and do not

project. The lateral flanks of the cardinal process bear a very low prominence, and continue forward into low ridges, without visible recurvature. The specimens show no sign of external radial ornament, either because they have been worn smooth or because of imperfect silicification.

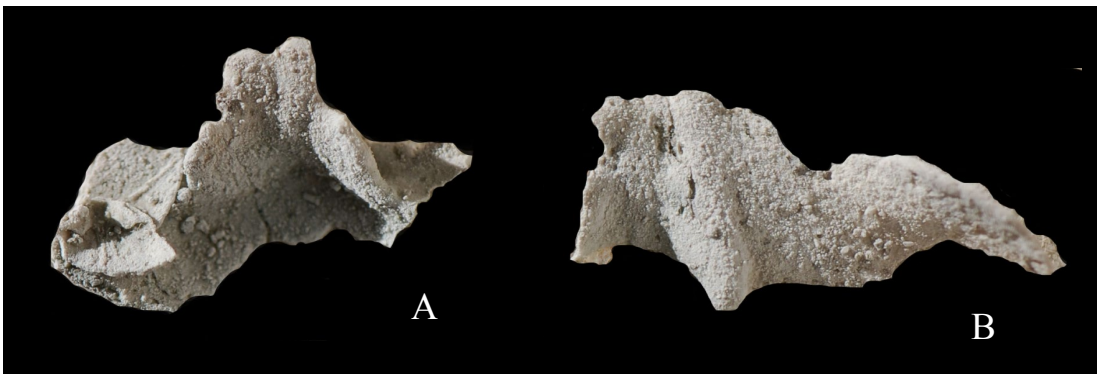


Fig. 111. Streptorhynchin sp. A, cardinal process and dental supports of dorsal valve GSC 140382, from internal aspect. B, ventral valve GSC 140383, internal aspect of dental ridges and teeth each side of pseudodeltidium. Specimens from GSC 53899, x3.

Superorder PRODUCTIFORMI Waagen, 1883

Order PRODUCTIDA Waagen, 1883

Suborder PRODUCTIDINA Waagen, 1883

Superfamily **ECHINOCONCHOIDEA** Muir-Wood & Cooper, 1960

Family **ECHINOCONCHIDAE** Muir-Wood & Cooper, 1960

Subfamily **TUBERSULCULINAE** Waterhouse, 1971

Tribe **TUBERSULCULINI** Waterhouse, 1971

Genus ***Krotovia*** Fredericks, 1927 (1928)

Diagnosis: Small thin-disced species, numerous spines arranged in quincunx over both valves, with slightly swollen not elongate ventral bases, intervening dimples prominent on dorsal valve, weakly developed marginal ridges and quadrifid cardinal process.

Type species: *Productus spinulosus* Sowerby, 1814, p. 155 from Lower Carboniferous (Asbian) of Fermanagh, Ireland, OD.

Krotovia? sp.

Fig. 112

Material: The internal mould of small ventral valve from GSC 53900, Wahoo Formation, Malcolm River.

Description: The specimen is small with well spaced moderately coarse spines, raised adductor platform and gently impressed diductor scars.

Fig. 112. *Krotovia*? sp. ventral interior GSC 140384 from GSC 53900, x3.

Suborder STROPHALOSIIDINA Waterhouse, 1975

Superfamily **STROPHALOSIOIDEA** Schuchert, 1913

Family **DASYALOSIIDAE** Brunton, 1966

Subfamily **ECHINALOSIINAE** Waterhouse, 2001

Tribe **ECHINALOSIINI** Waterhouse, 2001

Echinalosiin gen. & sp. indet. B

Fig. 113

Material: Two specimens with valves conjoined from GSC 53902, Wahoo Formation, Lisburne Group, Malcolm River.

Description: The two specimens have shell, and are irregular in shape. One is 8.5mm wide and 9.3mm long, with extended irregular ventral umbo, and large umbonal cicatrix 2.3mm wide. The anterior valve is irregularly rugose, whereas the dorsal valve has no fold, sulcus or rugae. The ventral interarea is high, short and almost planar at high angle to the commissure, with high narrow pseudodeltidium, opposed to a small notothyrium in the low dorsal interarea that lies in the same plane. Ventral spines are irregularly disposed, some prostrate, others slightly thicker and erect. The dorsal valve is crossed by low growth increments and has low irregularly spaced

tubercles, suggestive of possible spine bases, though this is not certain. In the other specimen, the ventral valve is irregularly rugose, with Fig. 114A illustrating a set of curved rugae suggestive, misleadingly it may be presumed, of an internal longitudinally oriented internal spire. It shows signs of comparable spines, but no cicatrix, and the interarea has been decorticated and partly destroyed. The dorsal valve surface is more irregular, also with low nodes, suggestive of small scattered spines.

Resemblances: The highly irregular shape is unusual, but in other features, the material comes close to *Echinalosia* Waterhouse, 1967, and the arrangement and nature of the spines over the two valves supports that relationship. It differs considerably from the Blackie Formation species (p. 95) in shape, size and nature of spines.

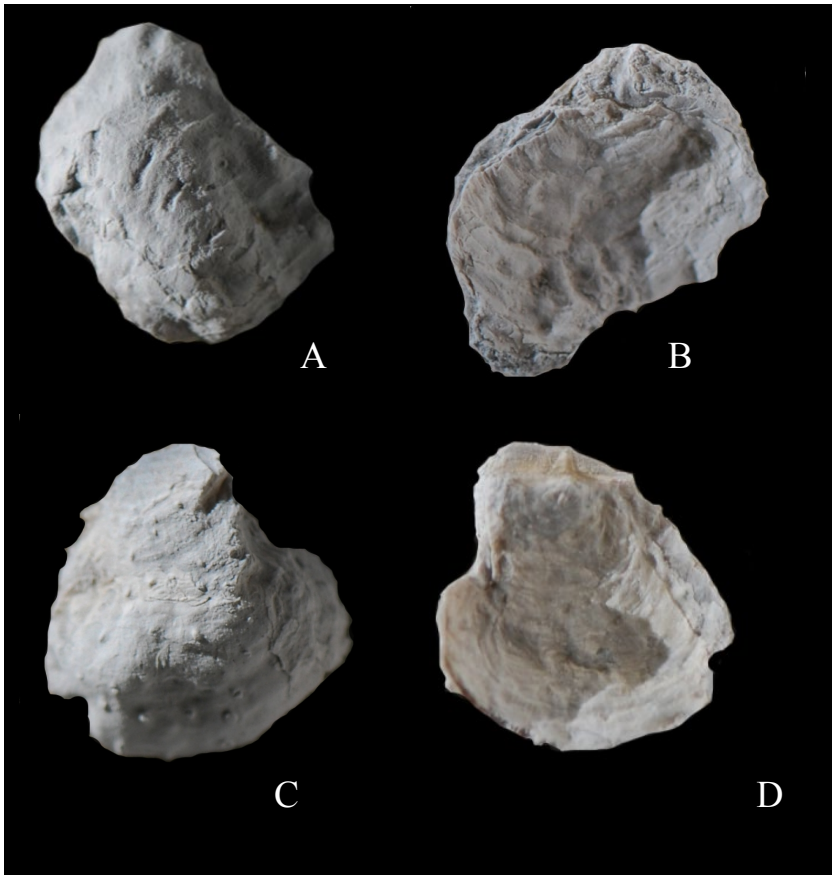


Fig. 113. Echinalosiin gen. & sp. indet. B. A, B, ventral and dorsal aspects of specimen with valves conjoined, GSC 140385. C, D, ventral and dorsal views of specimen with valves conjoined, GSC 140386. Specimens x5 from GSC 53902.

Suborder LINOPRODUCTIDINA Waterhouse, 2013

Superfamily **PAUCISPINIFEROIDEA** Muir-Wood & Cooper, 1960

Family **ANIDANTHIDAE** Waterhouse, 1968a

Subfamily **ANIDANTHINAE** Waterhouse, 1968a

Genus ***Protoanidanthus*** Waterhouse, 1986

Diagnosis: Small for subfamily and tribe, comparatively large ventral and dorsal ears, but dorsal ears not as extended as in several other anidanthin genera. Ventral spines few to numerous, with hinge row, no dorsal spines, dorsal valve not thickened, both valves costate. Adductor scars smooth as a rule, marginal ridge may be well developed.

Type species: *Protoanidanthus compactus* Waterhouse, 1986, p. 61 from Dresden Formation (Sakmarian), southeast Bowen Basin, Queensland, OD.

Discussion: This genus was named for an early Permian species found in the relateivly high paleolatitudes of Permian age in eastern Australia, and has been recognized in Late Carboniferous and Early Permian faunas of comparatively high paleolatitudes in both hemispheres. *Pseudomarginifera* Stepanov, 1934 is a poorly known genus, discussed in Waterhouse (2013, p. 325; 2018, pp. 218, 219), and possibly to be distinguished by its moderately large ventral ears and tendency to be nasute. The genus has been recorded only from northeast Russia in the Arctic, in beds of Permian age.

Protoanidanthus monstratus n. sp.

Fig. 114, 115

?1971 Linoproductinid Bamber & Waterhouse, p. 120, pl. 2, fig. ?11, ?12, 13.
?1971 Linoproductinid Bamber & Waterhouse, p. 122, pl. 3, fig. 6.

Derivation: monstratus – conspicuous, distinguished, Lat.

Diagnosis: Small shells with low convexity, distinguished by the ventral ears being as large as the relatively small ears (for the family) on the dorsal valve.

Holotype: Specimen GSC 140393 from Blackie Formation, figured in Fig. 115C, D, here designated.

Material: Specimens silicified, fourteen ventral valves and additional fragments and specimens, eighteen dorsal valves and additional fragments from GSC 53925, Blackie Formation (formerly Unit 2) at Cathedral Rocks. Four ventral valves from GSC 53880, Wahoo Formation, Lisburne Group, Barn Mountains.

Dimensions in mm: ventral valves

Width	Length	Height
22	15	9.7
12.5	10	3.5
11	10	4
7	6	2.5
dorsal valve:		
18	11	2
11.3	7.5	1.3
12.5	9	1.8

Description: Specimens small, transverse, ventral umbo slightly protruding beyond the hinge and weakly incurved, umbonal walls diverging at close to 90°, hinge at maximum width with moderately large ears weakly discriminated from the umbonal slopes, and weakly convex, then becoming concave towards the outer hinge, acute cardinal extremities. Dorsal valve gently concave without trail, ears moderately large, raised above disc and comparatively flat. Ventral valve without sulcus, and dorsal valve without fold. Both valves covered by fine costellae, counted at ten to twelve in 5mm over the anterior and mature ventral valve, and ten in 5mm anteriorly on the dorsal anterior of a mature valve. Increase is mainly by intercalation, but at least some costellae increase by branching. No ribs are developed over the ears of both valves, but on the mature ventral valve, short commarginal rugae cross the outer ears from the base of the umbonal slopes. In the dorsal valve, commarginal rugae are consistently present, and vary in number between seven and eleven, and they are very low or absent from the ears. Anteriorly they form low growth lamellae. There is no trail, which does raise the question of maturity, but it is deemed likely that the valve would have developed as in various anidanthid taxa, with slight thickening and abrupt termination. Spines are limited to the ventral valve. A row of comparatively strong erect spines lies along the hinge, increasing in strength away from the umbo and outwardly directed. Finer spines lie over the disc, emerging from the crest of costae, either erect or with slightly prolonged bases, and in some specimens occurring in a row across the shell.

Anteriorly there are small sharp projections at the intersections of commarginal rugae with interspaces between the ribs.

In most specimens, the ventral interior is dominated by ribs from the exterior. The adductor scars are small and posteriorly placed, and diductor scars also small and very lightly impressed. In the dorsal valve the cardinal process has two small lateral lobes, one each side of a deep median recessed lobe, with shallow median cleft from a ventral aspect. The median septal ridge immediately in front is broad with rounded crest, and becomes much thinner and lower between the adductor scars, extending approximately as far as mid-length. The adductor scars are smooth and subrounded triangular, not clearly subdivided into two pair. A long low round-crested ridge slopes obliquely outward and forward from the cardinal process in front of the hinge. Ribbing is visible over much of the valve, and there is no sign of brachial shields.

Resemblances: Full comparison is somewhat hampered by the paucity of shells, especially ventral valves, at full and late maturity, but the low convexity and relatively similar development of

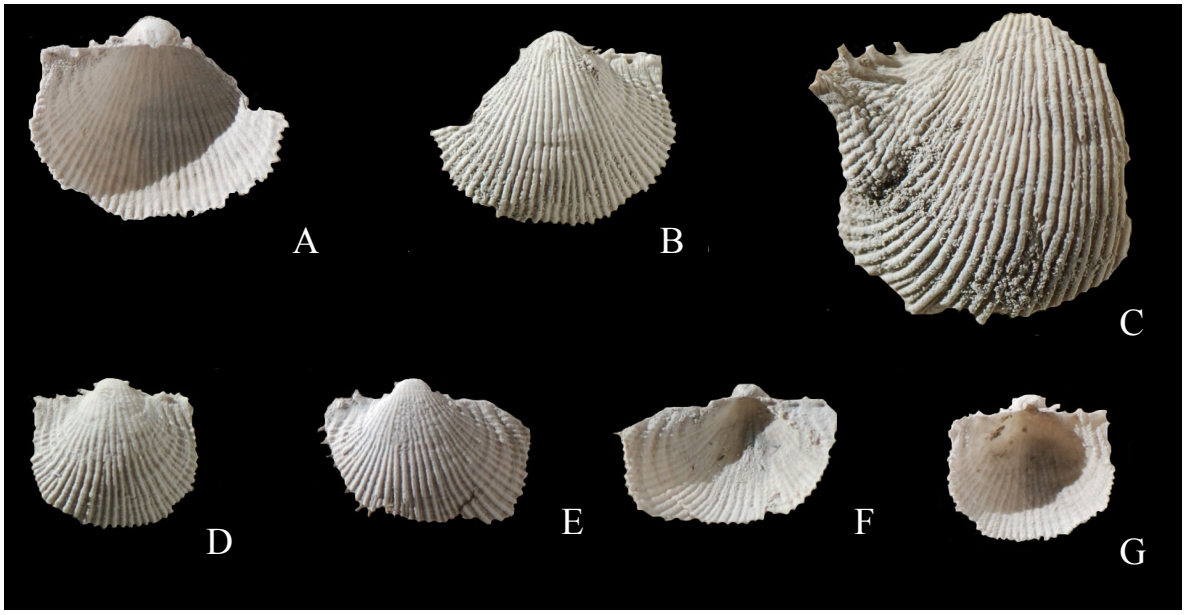


Fig. 114. *Protoanidanthus monstratus* n. sp. A, B, internal and external aspects of ventral valve, GSC 140387. C, external ventral valve, GSC 140388. D, G, external and internal aspects of ventral valve, GSC 140389. E, F, external and internal aspects of ventral valve, GSC 140390. Specimens from GSC 53925, x3.

ears on both ventral and dorsal valves mark highly distinctive features that distinguish the taxon from other species. The species would appear to be a very early member of the genus. Possibly the species is represented by a figure in Bamber & Waterhouse (1971, pl. 2, fig. 12) from the same locality, and possibly fig. 11 and 13 from underlying localities, but these specimens all have slightly stronger commarginal rugae than in present material, and the ventral valve in fig. 11 seems to have comparatively large ears. The latter two figured specimens are somewhat larger than present material and so could have represented mature specimens. They were recorded from GSC 53923 and 53924 at section 116J-4A of Cathedral Rocks in so-called Unit 2, now assigned to the Blackie Formation, close to GSC 53925, which provided some of the present material. A further possibly identical specimen is figured by Bamber & Waterhouse (1971, pl. 3, fig. 6) from GSC 53880 in the Wahoo Formation of Barn Mountains, and again, commarginal rugae are present, though ribs appear to have been stronger.

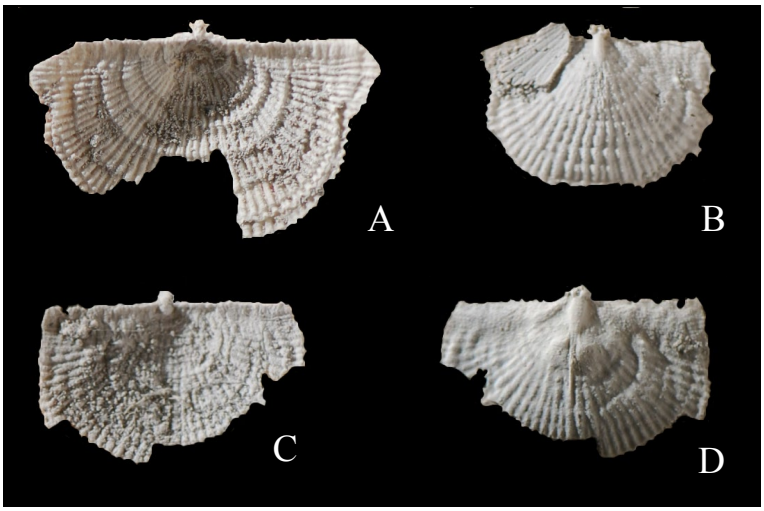


Fig. 115. *Protoanidanthus monstratus* n. sp. A, external aspect of dorsal valve, GSC 140391. B, internal dorsal valve, GSC 392. C, D, external and internal aspects of dorsal valve, GSC 140393, holotype. Specimens from GSC 53925, x3.

Superorder PENTAMERIFORMI Schuchert & Cooper, 1931

Order ORTHIDA Schuchert & Cooper, 1932

Superfamily **ENTELETOIDEA** Waagen, 1884

Family **RHIPIDOMELLIDAE** Schuchert, 1913

Subfamily **RHIPIDOMELLINAE** Schuchert, 1913

Genus ***Rhipidomella*** Oehlert, 1890

Diagnosis: Dorsibiconvex, fine costellae, strong dental plates and median ventral septum.

Type species: *Terebratula michelini* Léveillé, 1835, p. 39 from Visean of Belgium.

Rhipidomella borealis n. sp.

Fig. 116, 117

1971 *Orthotichia* sp. Bamber & Waterhouse, p. 120, pl. 2, fig. 1, 2.
1971 *Rhipidomella* sp. Bamber & Waterhouse, p. 122, pl. 2, fig. 8-10.

Derivation: boreas – north wind, Lat.

Diagnosis: Moderately large shells without ventral sulcus or groove, or dorsal fold. Ribs comparatively coarse, three to rarely four in 3mm as a rule.

Holotype: Specimen GSC 140394 figured in Fig. 116A, B, here designated.

Material: One dorsal valve from GSC 53882, Barn Mountains, six ventral valves and twenty five dorsal valves from GSC 53900, Malcolm River. Wahoo Formation, Lisburne Group.

Description: The most complete dorsal valve measures 21mm in width, 22mm long and 5mm high. Another broken specimen is 29mm wide. The specimens are silicified and other than in a few patches show poorly the external costation that typifies specimens of *Rhipidomella*. The walls of the ventral umbo diverge at approximately 90^{o}, and curve slightly into a greater angle, before rounding into obtuse cardinal extremities, and the remainder of the valve is of gentle convexity, with rounded margins and no sulcus. The dorsal valve is rather similar, slightly more inflated, bearing broader umbo measuring 110^{o} in angle, and without fold or sulcus. Ribs number three to less commonly four in 3mm at the anterior margin, and rarely up to six in 3mm.

There is a wide delthyrium, triangular to slightly arch-shaped, with angle close to 90^{o}, bordered on each side by a low ridge that terminates in a short stubby tooth. The posterior wall of the ventral valve becomes thickened, with a ridge continuing forward from the teeth. Narrow adductor ridges extend into an anterior elevation. To each side lie narrow diductor scars, slightly

wider than the adductors, and each bordered laterally by a well defined ridge. In the dorsal valve, the dental sockets are enclosed between the posterior wall and high narrow socket plates that have a socket ridge projection and continue well forward each as a lower broader ridge. In between lies a blunt knob-like cardinal process, bearing a median groove in only some specimens. The base in front is smooth, but a coarse ridge arises anteriorly, between two large oval muscle impressions, and in one specimen bears a shallow median groove.

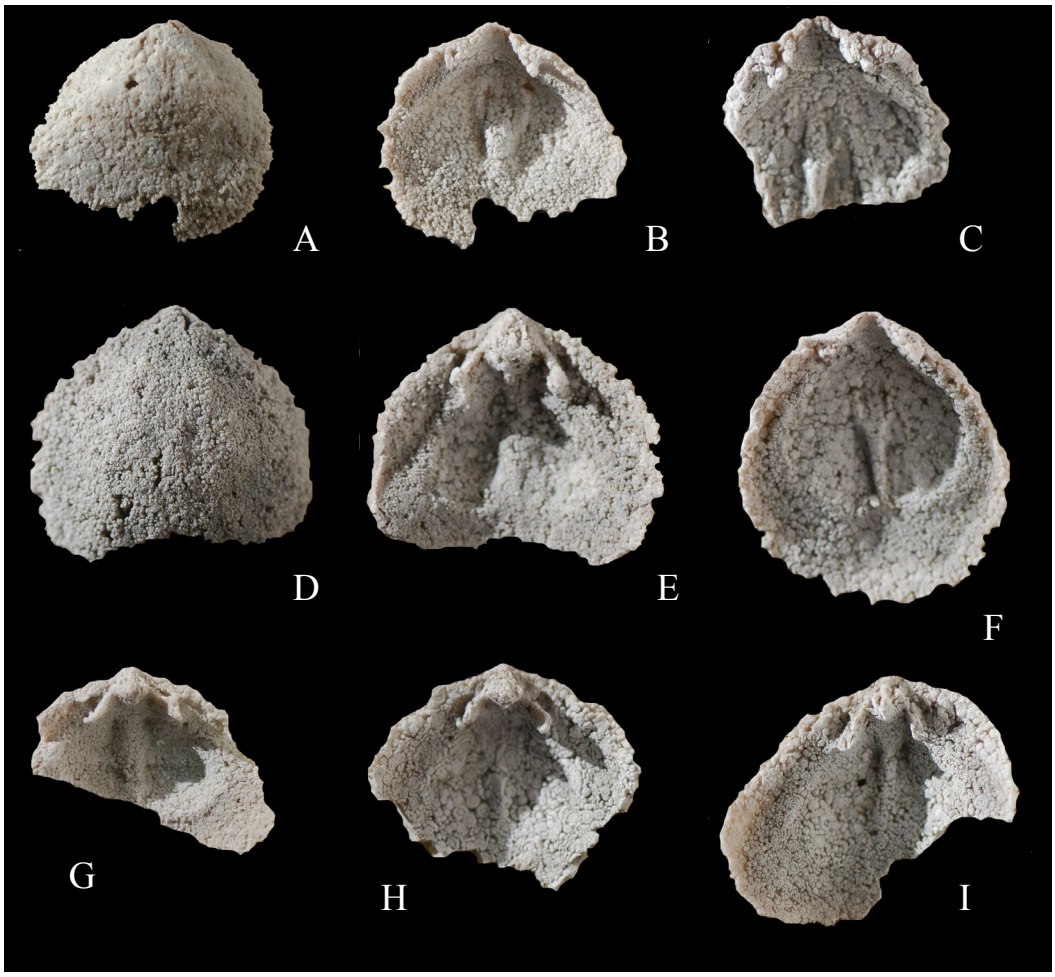


Fig. 116. *Rhipidomella borealis* n. sp. A, B, external and internal aspects of ventral valve, GSC 140394, holotype. The ribs have been lost largely from this specimen except to the lower right of the exterior during silicification. C, ventral interior, GSC 140395. D, E, external and internal views of dorsal valve, GSC 140396. The ribs have been lost. F, ventral interior, GSC 140397. G, dorsal interior, GSC 140398. H, dorsal interior, GSC 140399. I, dorsal interior, GSC 140400. Specimens from GSC 53900, x2.

Resemblances: *Rhipidomella* was recorded in Bamber & Waterhouse (1971) from the Wahoo Formation at GSC 53900 in section 117C-2, Malcolm River, and as *Orthotichia* sp. in the basal Ettrain Formation at GSC 53959 of Jungle Creek east section 116F-9 in the northern Ogilvie Mountains, just above the Hart River Formation (Bamber 1972, p. 49), and with no record of occurrences in what is now the Blackie Formation.

Identification of this species is based on shape, lack of sulcus, widely spaced dental flanges and teeth, small dorsal muscle scars, and coarse ribs. These features are consistent, even though in New South Wales, Campbell (1957) had found that valves were variable and the range of variation similar in most *Rhipidomella* from the Mississippian of New South Wales.

One of the closest species is judged to be *Rhipidomella carbonaria* (Swallow, 1858 – Trans. St Louis Acad. Sci. 1: 218), as summarized in Dunbar & Condra (1932, p. 52, pl. 2, fig. 1-4), in describing lower Missourian specimens from Kansas and Permian from the Hughes Creek shale of Nebraska. They were followed by Shimer & Shrock (1944, p. 355, pl. 24-26) and by Sturgeon & Hoare (1968, p. 25, pl. 2, fig. 13, 14) in describing material from scattered Atokan to Missourian levels in Ohio. The specimens are of similar shape, but much smaller, with two to three ribs in 1mm, distinctly finer than in the Canadian species. In addition, Sutherland & Harlow (1973, p. 18, pl. 1, fig. 9) compared a specimen from the Desmoinesian in New Mexico. *R. trapezoida* Sutherland & Harlow (1973, p. 18, pl. 1, fig. 10-12) from Morrowan rocks in New Mexico is small, with shallow dorsal sulcus and up to four ribs in 1mm. Gehrig (1958, p. 10, pl. 6, fig. 39-41) figured a similar specimen as *carbonaria* (not Swallow) from the Derry fauna of Desmoinesian age in New Mexico.

Another species with coarse ribbing was described as *Rhipidomella aitegouensis* Chen &

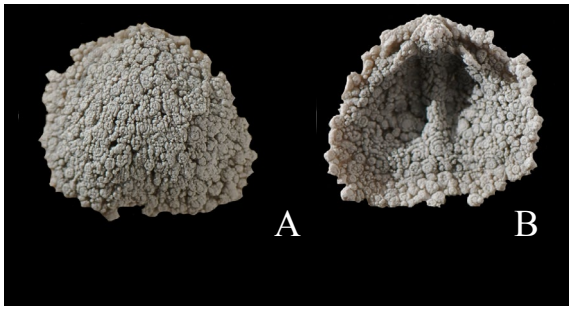


Fig. 117. *Rhipidomella borealis* n. sp., external and aspects of dorsal valve GSC 140401, from GSC 53900, x2. Ribs only faintly preserved only in patches.

Shi (2003, p. 161, pl. 9, fig. 1-5, text-fig. 30) from the upper Visean Heshilafu Formation of the Kunlun Mountains in northwest China. There are approximately two ribs in 1mm, with figures suggesting that ribs were apparently branching as well as intercalate, although the text stated that ribs were only intercalate. The hinge is short and umbones broad and inconspicuous, and the dorsal valve only slightly more inflated than the ventral valve, but overall more inflated than present material. Specimens are small, barely 9mm wide, rendering the strength of ribs unusual. Ranging into the overlying Serpukhovian faunas of the same formation, the medium-sized *R. radiata* Chen & Shi (2003, p. 162, pl. 9, fig. 6-12, text-fig. 31) has sharper umbones, with about thirteen to fifteen ribs in 5mm, limited growth lines, and more conspicuous umbones, as well as median dorsal groove and shallow anterior ventral sulcus.

There have been many reports of the biconvex species *Rhipidomella michelini* (Léveillé, 1835), some rather unlikely, such as the sulcate material figured by Volgin & Kushnar (1975, pl. 1, fig. 1, 2) from southern Fergana, and occurrences range as far as Western Australia (Roberts 1971). The species is especially well distributed in Europe, ranging from Middle Devonian to Upper Permian. Type specimens, as figured by Wright (1965) from the Visean of Belgium, are close to the present specimens in shape and inflation and lack of deep sulcus, but have finer ribs, at five or six in 3mm, and the socket plates with their projections lie closer together. The delthyrium is similarly wide, but the muscle scars are much larger. Excellent figures have been provided by Brunton (1968, p. 17, pl. 3, fig. 1-28, text-fig. 5) from Tournai in Belgium. They show a slight range of spacing for the teeth, but muscle scars, especially the ventral diductors, are much the same as in the present species. Similar interiors were figured for shells ascribed to *michelini* by Massa et al. (1974, text-fig. 2, 9, 10) from the Upper Visean of Tunisia, and the dorsal muscle scars in a Russian specimen are similarly large (Sarytcheva 1960, pl. 15, fig. 1, 2). Specimens from the Urals figured in Kalashnikov (1974, pl. 3, fig. 7-9) also have fine costellae, with ventral sulcus at mid-length and anterior dorsal sulcus. Another fine set of figures were provided by Thomas (1971, p. 25, pl. 21, fig. 1-16) from the Tournaisian to Visean of Western Australia, and some have a rather narrow hinge, and socket supports lie moderately close together. A number of the ventral valves have a shallow sulcus for most of their length, though

the anterior commissure is rectimarginate, and the specimens were identified with a query. There have been numerous reports of this species from Carboniferous faunas around the globe, and not all are in exact agreement. A number indicate a broad and shallow ventral sulcus, for example the Donets specimens figured by Rotai (1951, pl. 1, fig. 1, 2), though many are close, such as the specimens described by Licharew & Einor (1939, pl. 1, fig. 1) from the North Island in Novaya Zemlya. Specimens assigned to *Rhipidomella michelini* (Léveillé, 1835) from mainly the San Emiliano Formation and Valdeteja Formations, mostly of Bashkirian age in Spain, by Martínez-Chacón (1979, p. 63, pl. 3, fig. 12-15, pl. 4, fig. 1-15, text-fig. 6, 7) have a more swollen dorsal valve and tend to have a slightly more pronounced sulcus on each valve. Costae were counted at five in 3mm, compared with three to four in 3mm on present material. The cardinal process is narrower, and the dental sockets spaced further apart in the dorsal valve, and the teeth also more widely spaced, with wider delthyrium in present material, and other differences may be discerned, including slightly smaller and less defined muscle impressions.

Rhipidomella altaica Tolmachev, 1924; also described by Abramov (1965, p. 34, pl. 2, fig. 1, 2; 1974, p. 107, pl. 1, fig. 1-4) from Visean of northeast Russia is close in inflation and shape with more conspicuous sulcus in some specimens, and comparatively fine ribs, five to six in 3mm anteriorly. Several species of *Rhipidomella* were described by Lazarev in Sarytcheva (1977b) from Arctic Russia. *R. kharaulakhensis* Lazarev (in Sarytcheva 1977b, p. 22, pl. 1, fig. 1-6) from the lower Middle Carboniferous Tiksin Suite is large with broad very shallow ventral sulcus and another Middle Carboniferous species *R. pressula* Lazarev (in Sarytcheva 1977b, p. 24, pl. 1, fig. 7-10) is somewhat similar, at least as regards any comparison with the Canadian form. So is *R. orthogonia* Lazarev, of Bashkirian age (see Sarytcheva 1977b, p. 25, pl. 1, fig. 11-17) and *R. obesiconcha* Lazarev (in Sarytcheva 1977b, p. 23, pl. 1, fig. 19-21). On the other hand, *R. penniana dzhuvankensis* Besnossova (1968, p. 51, pl. 1, fig. 6-8) of Upper Carboniferous age in west Kazakhstan and Moscovian of the Arctic has a gentle ventral fold.

Rhipidomella diminutiva Rowley (1900, p. 261, pl. 5, fig. 41-43; Carter 1999, p. 112, Fig. 6oo-s) from a Tournaisian (Osagean) bioherm in the St Joe Formation of Oklahoma has a small narrow ventral umbo and narrow shallow dorsal sulcus, often confined to the umbonal region.

Ribs are fine. Amongst two species of comparable age, *R. jerseyensis* Weller (1914, p. 157, pl. 20, fig. 36-43 – see also Weller 1909, p. 205, pl. 12, fig. 8-10 for specimens which were called *michelinia* [not Léveillé] is smaller with broad ventral umbo and deeper dorsal sulcus, and *R. burlingtonensis* Hall, 1858 has larger broader ventral umbo, better developed ventral sulcus, weaker if any dorsal sulcus, and maximum width placed nearer to mid-length. Armstrong (1962, p. 46, pl. 6, fig. 8-11) ascribed specimens to *jerseyensis* from the Keating Formation, possibly of Osagean age. Externally, the Canadian specimens are close in shape and features other than finer ribs to *Rhipidomella* sp. of Armstrong (1958, p. 17, pl. 3, fig. 25-27) from the Kelly Formation of Osagean age in New Mexico. *R. elyensis* Lane (1962, p. 897, pl. 125, fig. 11-16) from the Atokan to early Desmoinesian Ely Group of Nevada is small and slightly more inflated than the present form, with large diductor scars.

Rhipidomella thiemi (White), as figured by Weller (1914, p. 155, pl. 21, fig. 8-27) from the Kinderhookian of Iowa, is somewhat similar in shape, but is smaller with well defined rims to the muscle scars, and fine ribs, four or five in 1mm. Derby (1874; Gonzalez 1952; Mendes 1956; Rocha-Campos & Archangelsky 1985) described a species as *Orthis*, now *Rhipidomella penniana* (Derby) from the Upper Carboniferous beds of Itaituba, Brazil, This species is close, with slightly narrower hinge and greater inflation.

Rhipidomella sp. of Nazer (1977, p. 3, pl. 1, fig. 25-27) has ribs counted at eight or nine in 3mm, and the dental projections from the sockets are relatively close together. The material came from late Visean (which possibly involved Serpukhovian) Killala Creek Limestone of the Munduberra area in Queensland.

Superorder ATRYPIFORMI Moore, 1952

Order ATHYRIDA Boucot, Johnson & Staton, 1964

Family **ATHYROIDEA** Davidson, 1881

Family **ATHYRIDAE** Davidson, 1881

Subfamily **SPIRIGERELLINAE** Grunt, 1965

Genus ***Composita*** Brown, 1845

Diagnosis: Roundly subpentagonal shells with variably developed sulcus and fold, foramen large and epi- to permesothyrid, no deltidial plates. Jugum athyriform.

Type species: *Spirifer ambiguus* Sowerby, 1822 from Derbyshire (Visean) of England, OD.

Composita largitas n. sp.

Fig. 118 - 121

?1971 *Composita* sp. Bamber & Waterhouse, p. 122, pl. 3, fig. 3.

Derivation: largitas – plentiful, Lat.

Diagnosis: Small biconvex shells with maximum width placed well forward, median groove in each valve, broadening into shallow ventral sulcus and rarely low broad fold anteriorly, shell smooth apart from growth lines and lamellae, thin short dental plates, cardinal plate resting on and elevated by socket plates, low median septum in each valve. Well developed crural bases.

Holotype: Specimen GSC 140408 figured in Fig. 120A, B, here designated.

Material: Three specimens with valves conjoined, seven dorsal valves and twenty ventral valves, all of them broken and incomplete, with fragments from GSC 53880, seven dorsal valves from GSC 53882 and three dorsal valves from GSC 54001. From Barn Mountains, Wahoo Formation, Lisburne Group.

Description: Present specimens are incomplete, but show most features well, and although the small size allows uncertainty about the state of maturity, the shell is robust and muscle scars well defined, suggestive of maturity. A ventral valve is 9mm wide, 8mm long and 2.5mm high. One of the larger dorsal valves is 11mm across. The ventral umbo is moderately prominent, not strongly incurved, with permesothyrid foramen, umbonal angle close to 90^{o}, and posterior walls concave in outline and sweeping out to well rounded cardinal extremities, with the maximum width placed just in front, close to mid-length. A very shallow and narrow median groove is present on most ventral valves. Most dorsal valves show no sign of a fold, and some have a shallow anterior sulcation. Both valves are smooth, apart from traces of growth increments.

Internally, the ventral teeth are small, and placed each at the end of a low inwardly concave dental flange, passing j ust inside the edge of the open delthyrium, and supported to the

floor of the valve by plates, which lie very close to or against the lateral wall: as a rule any posterior gap between the plate and lateral wall has been secondarily infilled. A large oval depression in the floor of the valve lies between the plates, and a second large depression lies in

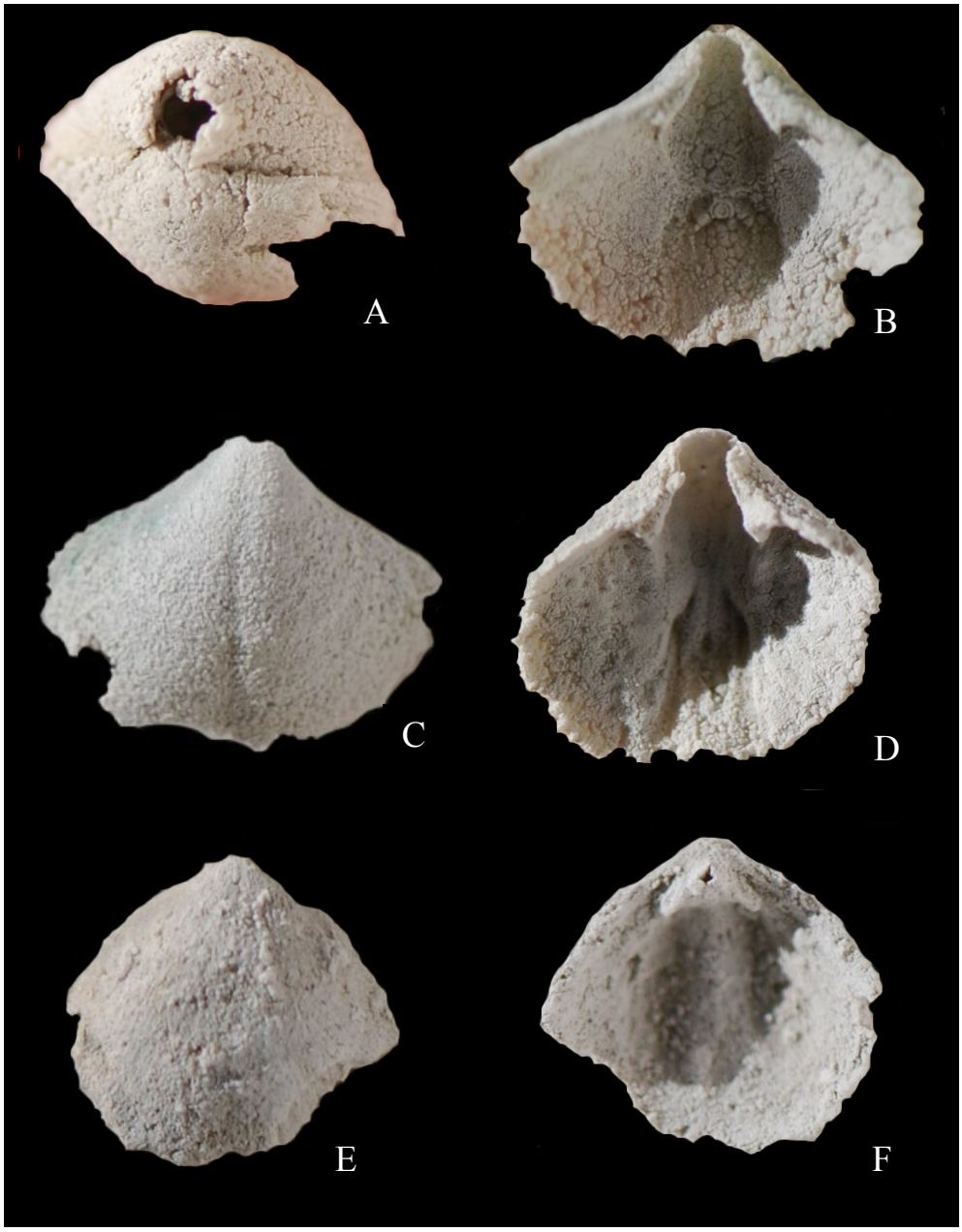


Fig. 118. *Composita largitas* n. sp. A, posterior view of specimen with valves conjoined, GSC 140402, showing damaged foramen. B, C, internal and external aspects of ventral valve, GSC 140403. D, ventral interior, GSC 140404. E, F, external and internal aspects of dorsal valve, GSC 140405. Specimens from GSC 53880, x6.

front, marked by faint longitudinal ridges, and representing the seat of muscles. The adductor scars are elongate and smooth, raised as a rule and divided by a slender groove, and the diductor scars are broader and impressed, extending behind and in front of the adductor scars (see Fig. 120D for example). To each side, the valve is slightly thickened and bears closely spaced dimples and papillae.

The dorsal socket plates are high, extending ventral to the umbo, and are joined by a broad cardinal plate suspended above the floor of the valve and traversed by low fine ridges (Fig. 121B). In more mature specimens the cardinal process has swollen in size and occupies much of the cardinal plate (Fig. 118F). A low well-formed median septal ridge commences under the cardinal plate and in front of the hinge, continuing for much of the length in one specimen but not the other from GSC 53880, and in this latter specimen the median part is occupied by thin shell, as possibly the seat of muscle scars, with thicker shell bearing low pustules to each side. The septum is also found in most of the specimens from GSC 53882. In one specimen the socket plates are each joined in front by a low ridge extending well forward.

Resemblances: A specimen with both valves conjoined from GSC 53903 in the Wahoo Formation at section 117C-2, Malcolm River (Bamber 1972, p. 160), as figured in Bamber & Waterhouse (1971, pl. 3, fig. 1, 2) lacks the ventral groove and has an anterior dorsal fold, suggesting a

Fig. 119. *Composita largitas* n. sp. A, internal aspect of ventral interior GSC 140406 with dorsal cardinalia attached. B, exterior of ventral valve GSC 140407. Specimens from GSC 53880, x6.

different species. The interior of a dorsal valve figured from the same locality in Bamber & Waterhouse (1971, pl. 3, fig. 3) might belong to the same species, or to the present species.

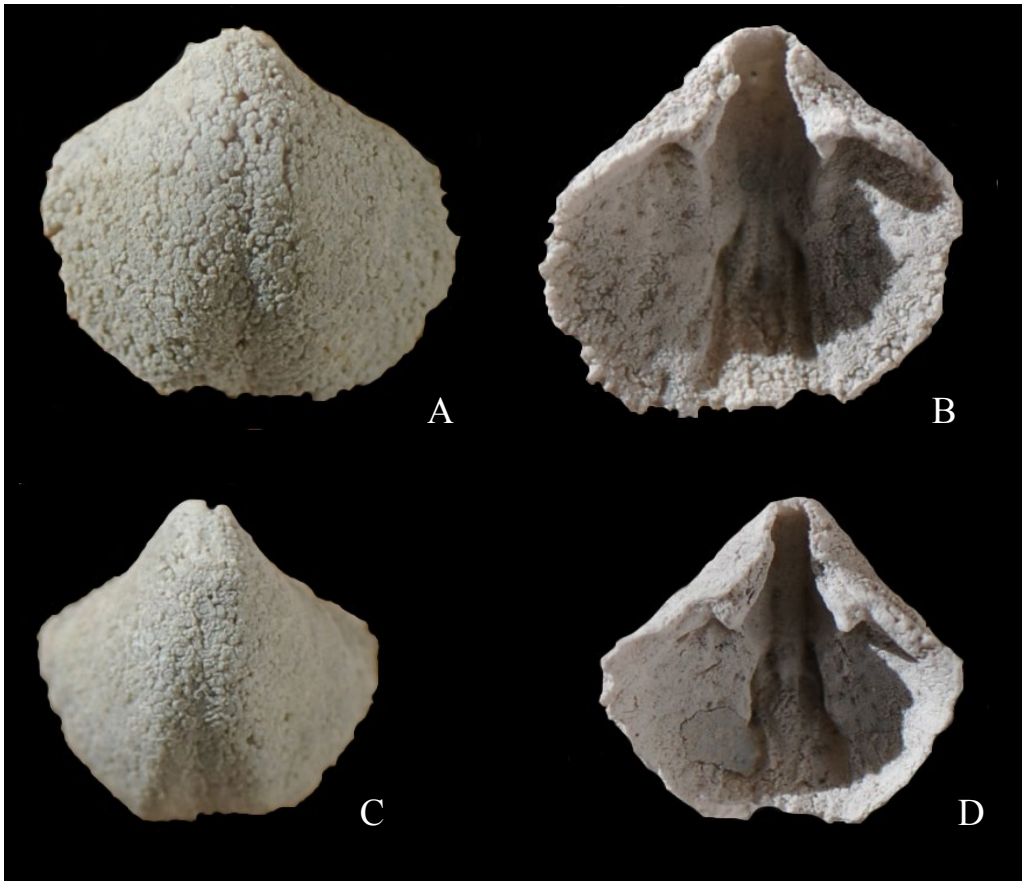


Fig. 120. *Composita largitas* n. sp. A, B, external and internal aspects of ventral valve, GSC 140408 holotype, C, D, external and internal aspects of ventral valve, GSC 140409. Specimens from GSC 53880, x6.

Several *Composita* species identified by Sutherland & Harlow (1973) from New Mexico are moderately close in shape. *C. gibbosa* Mather (1915, p. 204, pl. 13, fig. 16-18) from Morrowan of Arkansas and Oklahoma, also reported by Sutherland & Harlow (1973, p. 64, pl. 14, fig. 13, 14) from Morrowan beds of New Mexico, is somewhat similar, though not exactly the same. *C. deflecta* Mather (1915, p. 203, pl. 14, fig. 1-3; Sutherland & Harlow 1973, p. 64, pl. 14, fig. 15-17) from Arkansas and New Mexico is much closer in shape. Some develop an anterior

sulcus, and do not appear to have an anterior dorsal fold. *Composita ovata* Mather, 1915 is reported to range through Morrowan to Virgilian by Dunbar & Condra (1932, p. 370, pl. 43, fig. 14-19), Stevens (1962, pl. 91, fig. 5) and Sutherland & Harlow (1973, p. 67), and compared to specimens from mid-Pennsylvanian of Venezuela by Benedetto (1980). Some show a low broad dorsal fold, and this is coupled with a better-defined ventral sulcus. The present species is also a little wider anteriorly. Sutherland & Harlow (1967, p. 1079; 1973, p. 66ff) drew attention to the problem raised by morphological variation in some of their *Composita* collections, and left the matter open for further analyses. From Desmoinesian beds of New Mexico, *C. umbonata* Sutherland & Harlow (1973, p. 67, pl. 14, fig. 22, 23) is more inflated with shallow dorsal as well as ventral sulcus.

For *Composita derrya* Gehrig (1958, p. 12, pl. 4, fig. 9-27) from the Desmoinesian Stage, Derry level in New Mexico, the maximum width lies near mid-length, though some more closely approach the present form in having maximum width placed further forward. A Desmoinesian form described as *Composita subquadrata* Hall, 1858 from the Chester Group of Illinois (see also Weller 1914, p. 489, pl. 81, fig. 1-15) is also somewhat similar in shape and has a dorsal fold anteriorly and broad short anterior ventral sulcus. Specimens identified with *C. subtilita* (Hall, 1852) from the mid-Pennsylvanian Naco Formation of central Arizona by Brew & Beus (1976, p. 901, pl. 11, fig. 1-11, text-fig. 5-7) are comparable in size, but are slightly narrower with less defined anterior dorsal fold, whereas a figure provided by Stevens (1962, pl. 91, fig. 6) suggests a moderately inflated shell with long ventral sulcus. A large suite of specimens from the early Permian of Bolivia has been identified with Hall's species by Kozlowski (1914, pl. 11, fig. 1-46) and Samtleben (1971, pl. 8, fig. 12-37, text-fig. 17-22) and these are moderately close, with broad flat-floored anterior ventral sulcus, often with a median groove extending posteriorly for up to half the length of the shell. As a rule, the specimens are slightly narrower than present material. Comparable material was described as *C. quadrata* Butts by Branisa (1965, pl. 67, fig. 7, 8, 12, 14), *C. transversa* Branisa (1965, pl. 67, fig. 9-11), and other species in Branisa (1965), as well as the species *subtilita* in Ahfield & Branisa (1960, pl. 7, fig. 7), with further synonymies in Grinnel & Andrews (1964, p. 235, pl. 37, fig. 3, 4, pl. 38, fig. 1, 2, pl. 39, fig. 3, 4, 9, 10) and

Samtleben (1971, p. 91). Hall's material (1852, pl. 4, fig. 1a-2b) is only moderately close.

From the Visean Group of Nova Scotia, specimens identified by Bell (1929, p. 132, pl. 20, fig. 16-23) with *Composita dawsoni* (Hall & Clarke, 1894, p. 95, pl. 47, fig. 32, 34; Hall & Clarke 1895, p. 359, pl. 9, fig. 14, 16) of Illinois are more inflated, but of similar shape and much the same dorsal fold, although the ventral sulcus is no more than a narrow groove, if present. The species was originally described as *Seminula*, and transferred to its senior synonym *Composita* by Beede (1911, p. 180). Bell (1929, p. 133) drew attention to unusual aspects of the accessory lamellae. From the same group in Nova Scotia, *C. windsorensis* Bell (1929, p. 133, pl. 21, fig. 7-18) tends to have a groove-like sulcus traversing much of both valves.

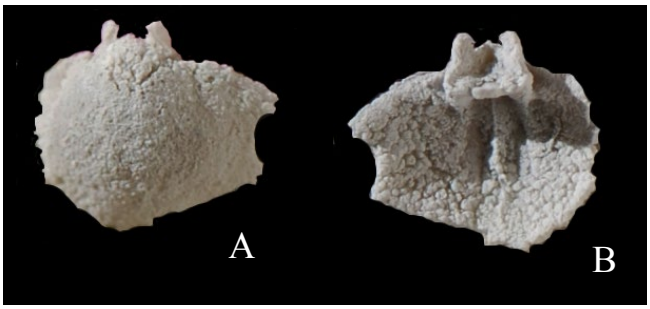


Fig. 121. *Composita largitas* n. sp., external and internal aspects of dorsal valve GSC 140410, from GSC 53880, x6.

Superorder SPIRIFERIFORMI Waagen, 1883

Order SPIRIFERIDA Waagen, 1883

Suborder MARTINIIDINA Waterhouse, 2016

Infrasuborder MARTINIIMORPHI Waterhouse, 2016

Superfamily **INGELARELLOIDEA** Campbell, 1959a

Family **RORESPIRIFERIDAE** Waterhouse, 1998

Subfamily **RORESPIRIFERINAE** Waterhouse, 1998

Genus ***Rorespirifer*** Waterhouse & Piyasin, 1970

Diagnosis: Small little inflated almost smooth shells with long adminicula and long tabellae. Shell surface densely covered by minute spinules.

Type species: *Rorespirifer ruinosus* Waterhouse & Piyasin, 1970 from Rat Buri Limestone

(Roadian) of Thailand, OD.

Discussion: This subfamily has genera ranging from Devonian into Permian, as discussed in Waterhouse (2016, pp. 80-83), and the present species cannot be separated generically from type *Rorespirifer*, although much older.

The type species, *Rorespirifer ruinosus*, is very like material from much the same stratigraphic level in south Thailand that was described as *Martiniopsis trimmata* by Grant (1976, p. 226, pl. 62, fig. 1-21), but Grant (1976, p. 226) considered that micro-ornament in his species was regularly concentric, unlike the fine crowded spinules reported and figured for *Rorespirifer* (see Waterhouse & Piyasin 1970, pl. 29, fig. 15). Grant (1976, p. 226) asserted that the figure of micro-ornament in *Rorespirifer* did not show spinular ornament, but I can see it clearly in the figure, as composed of tiny crowded spinules. Grant (1976, p. 221) stated that *Martiniopsis* micro-ornament was “finely reticulate” in the type species, *M. inflata* Waagen, 1883, from the Chhidru Formation of the Salt Range, Pakistan, but I believe from examination of types at Kolkata that the ornament on the rather worn type material only shows traces of commarginal growth lines. Ornament on the older species *M. subpentagonalis* Waagen from the older Amb Formation of same area consists of short grooves in quincunx, as in Carter & Gourvennec (2006, p. 1762) and Waterhouse (1964, p. 146; 1965, pp. 167, 168; 1966, p. 56), with commarginal growth increments variably developed. Brown (1953) in a major revision of the two species regarded the two species as synonymous, but offered no comment on micro-ornament.

Rorespirifer prodigium n. sp.

Fig. 122 - 127

1971 “*Martiniopsis*” sp. Bamber & Waterhouse, p. 120, pl. 2, fig. 19-21.

Derivation: prodigium – a sign, portent, Lat.

Diagnosis: Less transverse than the type species, without sulcus or fold, no clearly defined ctenophoridium. Micro-ornament of minute spinules.

Holotype: Specimen GSC 140411 illustrated in Fig. 122A, C, here designated.

Material: Three broken ventral valves and a dorsal valve, with further fragments, from GSC

53925, Cathedral Rocks, Blackie Formation. From the Wahoo Formation, nine ventral valves and three dorsal valves from GSC 53880, Barn Mountains, and fourteen ventral valves and two dorsal valves from GSC 53900 at Malcolm River.

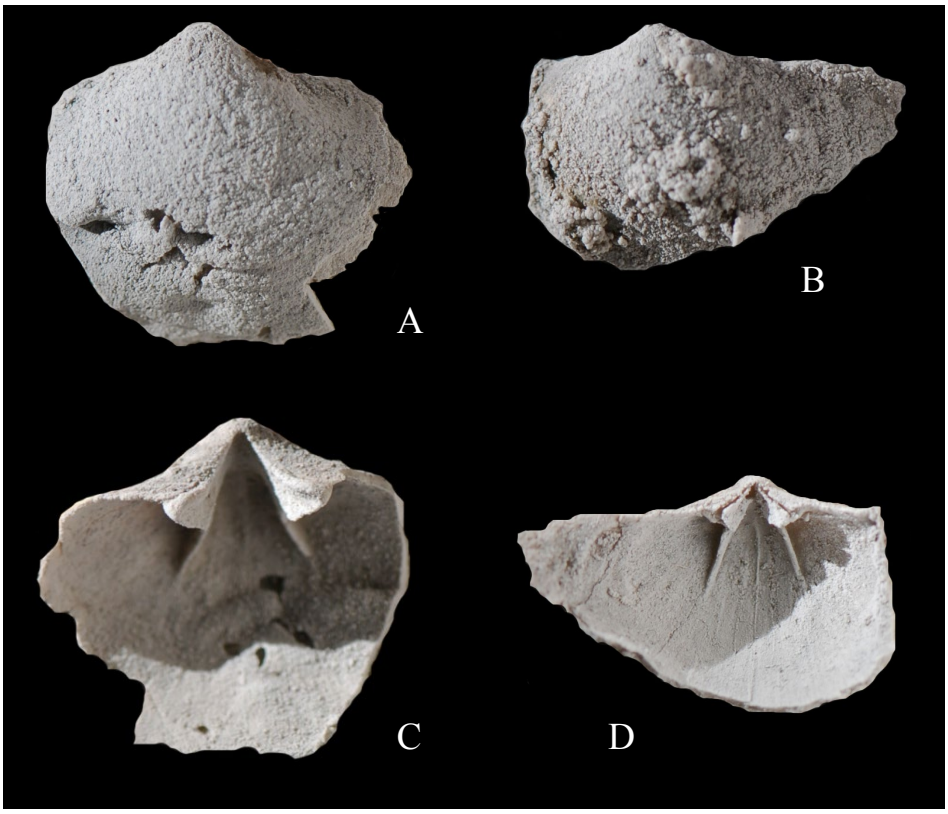


Fig. 122. *Rorespirifer prodigium* n. sp. A, C, external and internal aspects of ventral valve, GSC 140411 holotype. B, D, external and internal aspects of dorsal valve, GSC 140412. Specimens from GSC 53925, x3.

Description: Specimens medium-small, the largest measuring about 30mm in width. The ventral valve has a slightly protruding umbo and posterior walls diverging at angle of approximately 90°, and curving out to obtuse cardinal extremities, with well defined, high but narrow and gently concave interarea bearing growth striae. The external surface of the shell lacks a sulcus except for a shallow anterior depression in one specimen. The dorsal valve is less inflated with no fold or plicae. In some specimens the interarea is of negligible height, in others, well defined and gently concave. Micro-ornament on both valves consists of crowded tiny pustules varying a little in size

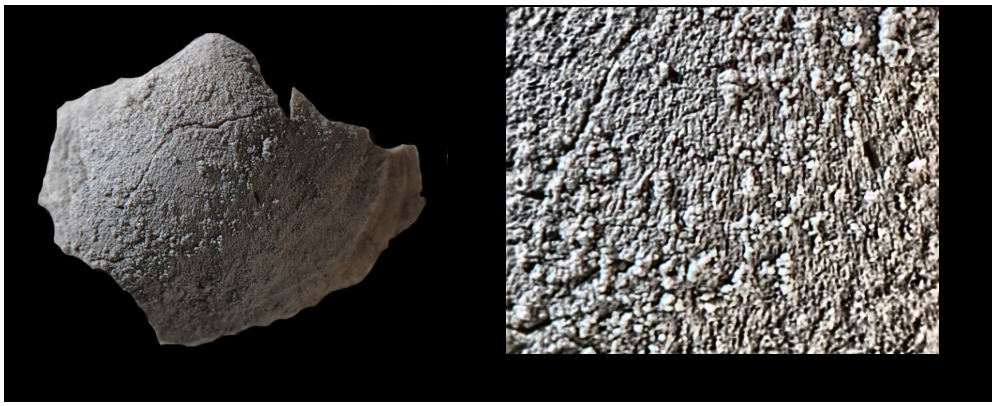


Fig. 123. *Rorespirifer prodigium* n. sp.. A, ventral valve GSC 140413 from GSC 53900, x3. B, detail of micro-ornament on same specimen, x7, showing recumbent fine spinules, such as developed on some specimens of type *Rorespirifer,* though shorter spinules are prevalent in both the type species and in this species.

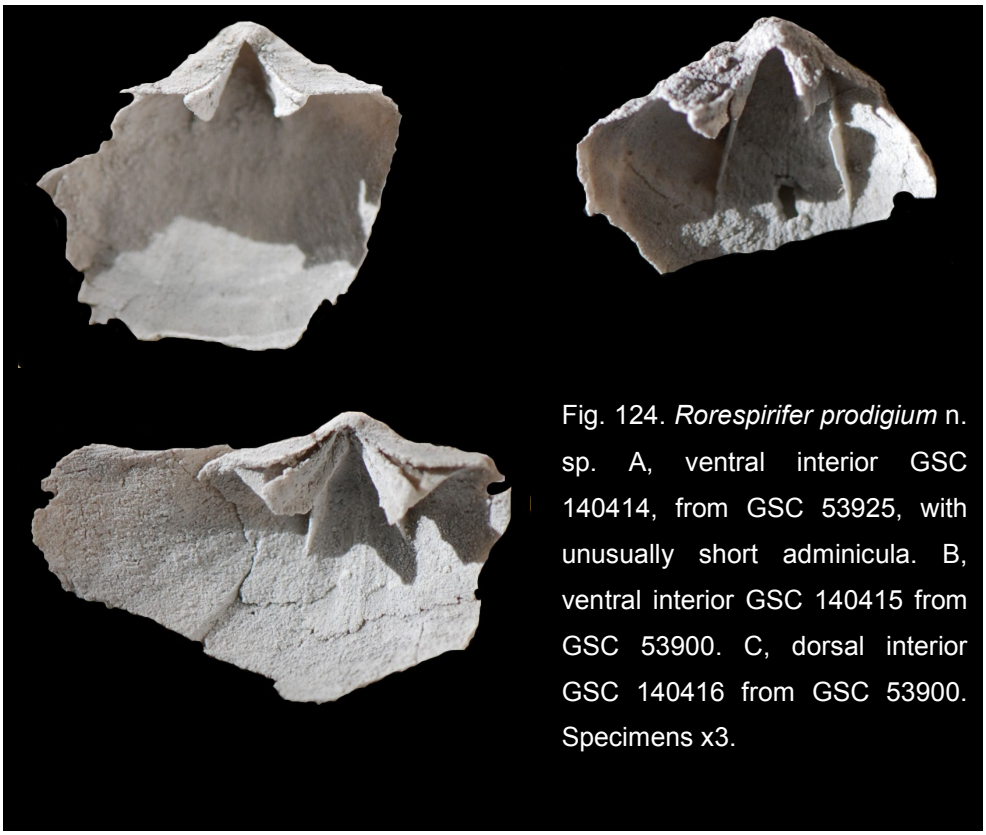


Fig. 124. *Rorespirifer prodigium* n. sp. A, ventral interior GSC 140414, from GSC 53925, with unusually short adminicula. B, ventral interior GSC 140415 from GSC 53900. C, dorsal interior GSC 140416 from GSC 53900. Specimens x3.

over the shell, from three to six up to eight in 1mm along commarginal rows, spaced at four in 1mm over mid-length on the dorsal valve. That applies to most specimens, but one ventral valve

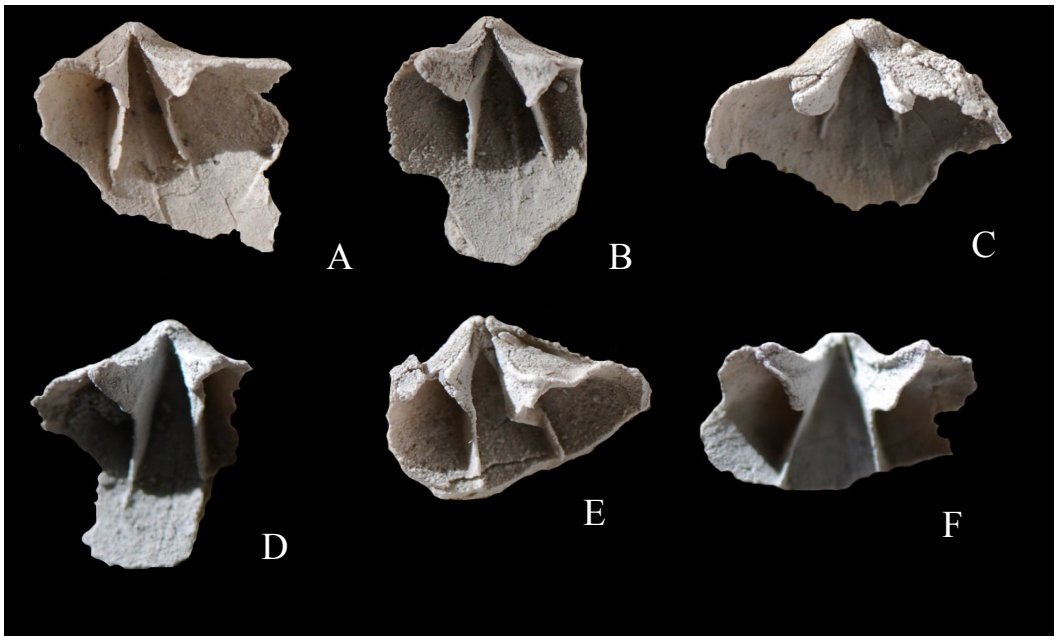


Fig. 125. *Rorespirifer prodigium* n. sp. A, B, C, interior of ventral valve for specimens GSC 140417 - 140419, from GSC 53900. D, E, F interior aspect of ventral valves for specimens GSC 140420 - 140422, from GSC 53880. Specimens x3.

Fig. 126. *Rorespirifer prodigium* n. sp. A, dorsal interior GSC 140423 from GSC 53900, x3. B, dorsal interior GSC 140424, from GSC 53925, x3.

is exceptional in showing more elongate slender apparent spinules (Fig. 123B).

Aminicula are long and diverging as a rule, supporting high scapular-shaped dental plates each side of an open delthyrium with angle of 70°, bordered by low dental ridges projecting

into well formed teeth. Muscle scars are obscure. In the dorsal valves there are long tabellae which support low crural plates that below the commissure block much of a wide low notothyrium. A low long median ridge is present in some of the dorsal valves, and shallow elongate muscle scars lie between the anterior ends of the tabellae. There is no clearly defined ctenophoridium.

Resemblances: Ventral valves that belong to this species were figured from the lower Ettrain Formation in GSC 53973 at section 116F-9, Jungle Creek East (Bamber 1972, p. 46) and GSC 53926 in the lower Ettrain Formation at section 116J-4A, Cathedral Rocks, in Bamber & Waterhouse 1971, p. 243). Compared with species assigned to *Martiniopsis* from the Permian Period, these specimens have very well developed adminicula and tabellae, and different micro-ornament of pustules or tiny spinules rather than elongate grooves.

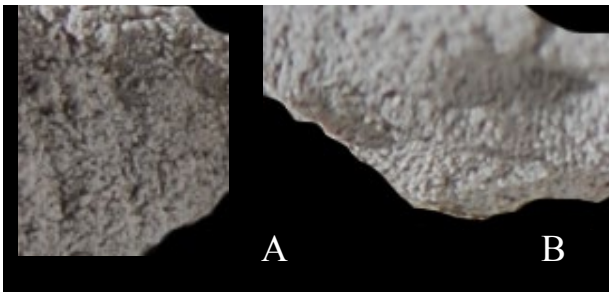


Fig. 127. *Rorespirifer prodigium* n. sp. A, micro-ornament on GSC 140412, x12. See Fig. 122B. B, micro-ornament of pustules GSC 140411. See Fig. 122A, x9. Specimens from GSC 53925.

Rorespirifer ruinosus Waterhouse & Piyasin (1970, p. 156, pl. 29, fig. 8-14) lacks a ventral sulcus like the present form, is more transverse, and has a better developed and sessile ctenophoridium. Micro-ornament consists of up to ten tiny spinules in 1mm and mostly very short, although some were recorded as being up to two mm long. It is of Roadian age, notwithstanding claims that it was upper Artinskian (see Grant, 1976; Waterhouse 1981).

Infrasuborder CHORISTITIMORPHI Waterhouse, 2016

Superfamily CHORISTITOIDEA Waterhouse, 1968b

Choristitoid gen. & sp. B

Fig. 128

1971 *Choristites* sp. Bamber & Waterhouse, p. 122, pl. 3, fig. 4, 5.

Material: Five ventral valves from GSC 53880 and three ventral valves from GSC 53900, Wahoo Formation, Lisburne Group.

Description: Four to five distinct plicae, becoming costate anteriorly. The specimen figured in Bamber & Waterhouse (1971) is larger and is more complete and is well preserved. It also came from GSC 53880. The lack of a dorsal valve hinders closer identification.

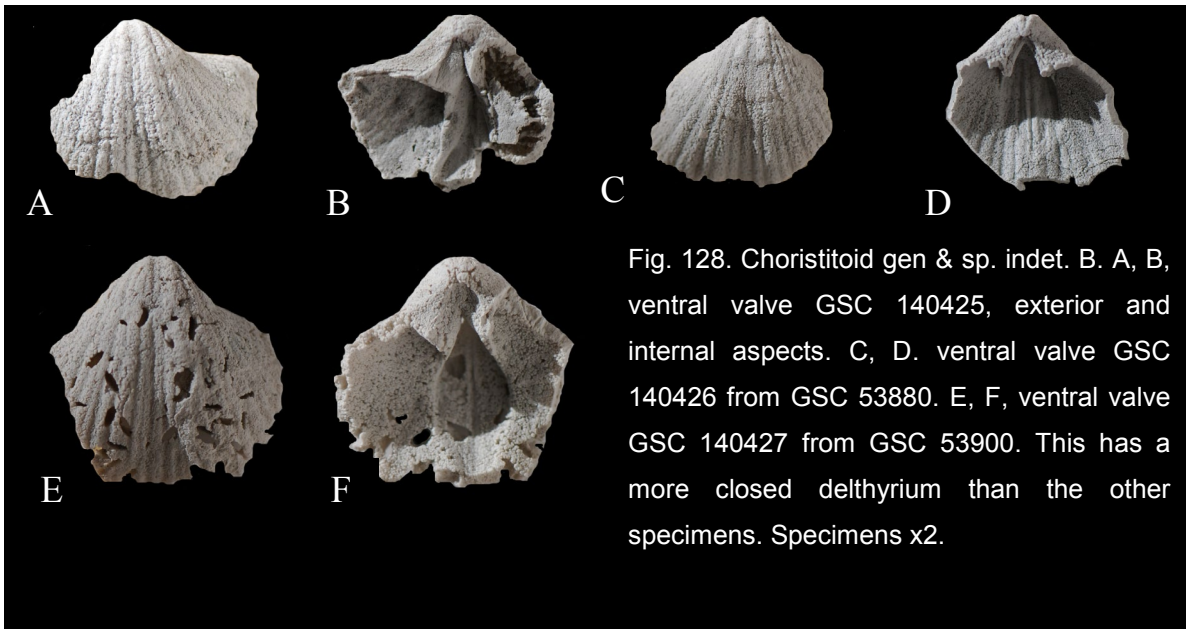


Fig. 128. Choristitoid gen & sp. indet. B. A, B, ventral valve GSC 140425, exterior and internal aspects. C, D. ventral valve GSC 140426 from GSC 53880. E, F, ventral valve GSC 140427 from GSC 53900. This has a more closed delthyrium than the other specimens. Specimens x2.

Choristitoid gen. & sp. indet. C

Fig. 129, 130

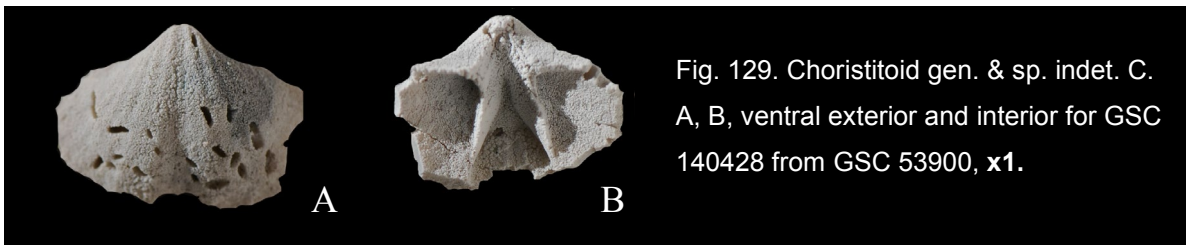


Fig. 129. Choristitoid gen. & sp. indet. C. A, B, ventral exterior and interior for GSC 140428 from GSC 53900, **x1.**

Material: Three broken ventral valves from GSC 53900, Wahoo Formation, Lisburne Group.

Description: The specimens have broad plicae that are indistinctly and finely costate anteriorly, and costate sulcus. Open delthyrium and moderately long adminicula.

Fig. 130. Choristitoid gen. & sp. indet. C. A, B, ventral exterior and interior for GSC 140429 from GSC 53900, x2.

Family **PURDONELLIDAE** Poletaev, 1986

Diagnosis: Members distinguished from other Choristitoidea by development of subdelthyrial connector plate. No tabellae.

Discussion: The connector plate lies between the adminicula and the dental plates, and spans the delthyrial gap below the ventral umbo.

Purdonellid gen. & sp. indet. A

Fig. 131 – 133

1971 ?Choristitinid Bamber & Waterhouse, p. 122, pl. 3, fig. 8, 9.

Diagnosis: A few broad round-crested plicae, and sulcus. Connector plate.

Material: Seven ventral valves which have been silicified, from GSC 53925, Blackie Formation in Ogilvie Mountains. Eighteen fragmentary ventral valves and additional fragments from GSC 53880, Wahoo Formation, Barn Mountains.

Description: Specimens small, one measuring 18mm wide and estimated to have been 17mm

and 6mm high, with long prominent ventral umbo displaying an angle of 90°, clearly defined sulcus widening at almost 20°, with gently concave floor, cardinal extremities now obtuse, possibly due to breakage or incomplete silicification. There are five pairs of low round-crested plicae, the inner ones tending to subdivide into costae anteriorly. Internally, adminicula are long

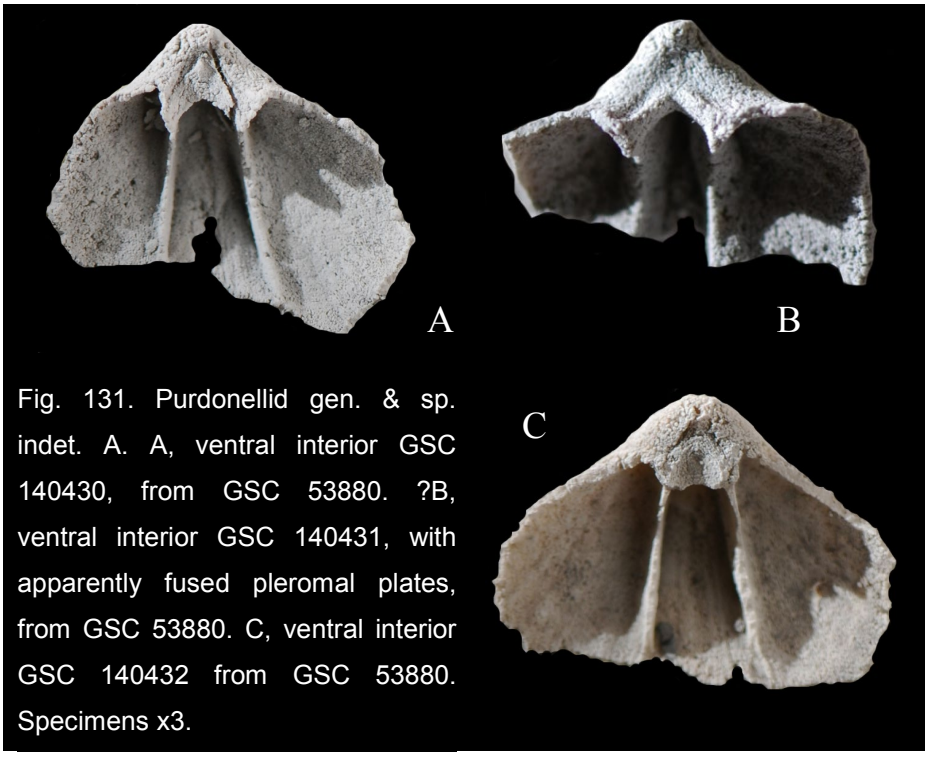


Fig. 131. Purdonellid gen. & sp. indet. A. A, ventral interior GSC 140430, from GSC 53880. ?B, ventral interior GSC 140431, with apparently fused pleromal plates, from GSC 53880. C, ventral interior GSC 140432 from GSC 53880. Specimens x3.

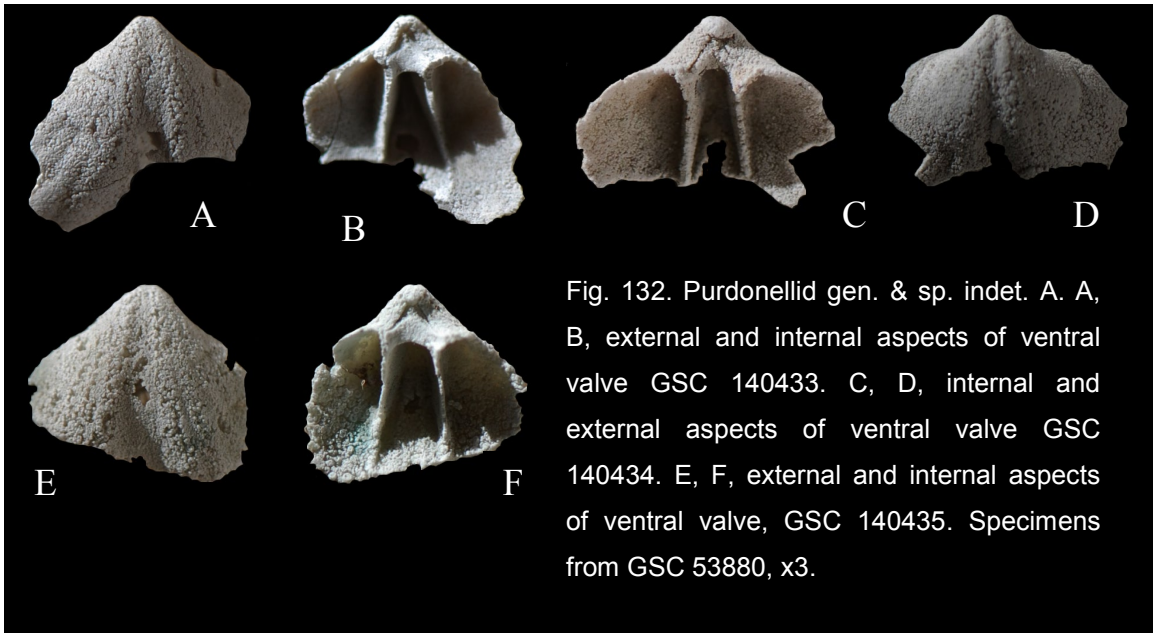


Fig. 132. Purdonellid gen. & sp. indet. A. A, B, external and internal aspects of ventral valve GSC 140433. C, D, internal and external aspects of ventral valve GSC 140434. E, F, external and internal aspects of ventral valve, GSC 140435. Specimens from GSC 53880, x3.

Fig. 133. Purdonellid gen. & sp. indet. A. A, B, external and internal aspects of ventral valve GSC 140436. C, D, external and internal aspects of ventral valve GSC 140437. Specimens from GSC 53880, x3.

and diverge at close to 20°, supporting dental plates that vary in height, in some as high as the adminicula, in others much lower. Teeth are well developed and leave dental ridges that border the delthyrium. A transverse plate is developed across the delthyrium, flat or weakly concave outwards, and seemingly placed high on the dental plates, or in other specimens, between the dental plate and adminicula on each side. Apparently its position varied somewhat on different specimens.

Resemblances: These specimens are apparently immature and incomplete, and without the dorsal valve, so that identification is insecure. The presence of a delthyrial plate suggests a

possible identification with *Purdonella* Reed, 1944. A previously figured specimen in Bamber & Waterhouse (1971) is much larger than the other specimens, and also came from GSC 53880 in the Wahoo Formation.

Discussion: The family position is identified through the presence of a connector plate which spans the delthyrial gap under the ventral umbo. But in some specimens, there is no obvious connector plate joining the adminicula and dental plates, and instead the first formed part of the delthyrium is apparently closed by pleromal plates (see Fig. 131B): the connector plate is no longer obviously present, possibly lost, possibly never developed. Pleromal plates were named by Campbell (1959a) for *Ingelarella* Campbell, and are widely developed in Spiriferida as outgrowths from the dental rims left by the growing teeth. Such specimens require further study, and they may well prove to belong to choristitoid stock, but the limited range of available material hinders further enquiry.

Purdonellid gen. & sp. indet. B

Fig. 134

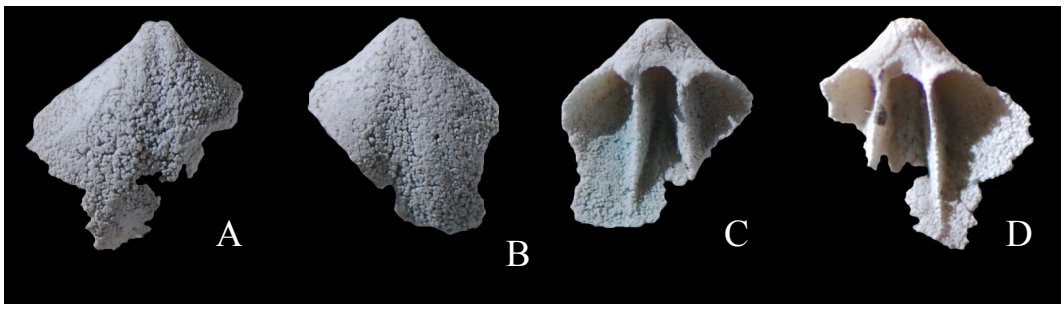


Fig. 134. Purdonellid gen. & sp. indet. A, D, external and internal aspects of ventral valve GSC 140438. B, C, external and internal aspects of ventral valve GSC 140439. From GSC 53880, x3.

Material, Description: This is a likely variant of Purdonellid A, probably not constituting a full species, although full information is lacking, given the absence of the dorsal valve and the immature nature of the specimens. It is represented by some eight ventral valves from GSC

53880 of the Wahoo Formation in the Barn Mountains. These are very close to Purdonellid gen. & sp. A, but the shell is almost smooth apart from the sulcus and traces of faint costae.

Purdonellid gen. & sp. indet. C

Fig. 135

Material, Description: Five ventral valves from GSC 53880, Wahoo Formation, displaying numerous closely spaced and well defined ribbing, with weak suggestion of plication. The connector plate, dental plates and adminicula are developed much as in the specimens referred to Purdonellid gen. & sp. indet. A, and the muscle scars form a well defined field.

Fig. 135. Purdonellid gen. & sp. indet. C. A, B, external and internal aspects of ventral valve, GSC 140440. Specimen from GSC 53880, x3.

Suborder SPIRIFERIDINA Waagen, 1883

Superfamily **PAECKELMANNELLOIDEA** Ivanova, 1972

Family **PTEROSPIRIFERIDAE** Waterhouse, 1975

Genus ***Spiriferinaella*** Fredericks, 1926

Diagnosis: Transverse and often alate shells with smooth fold, and sulcus smooth or with weak sulcal rib, few simple plicae, fine growth lamellae.

Type species: *Spirifer artiensis* Stuckenberg, 1898, p. 266 from Upper Paleozoic of Russia, OD.

Spiriferinaella sp.

Fig. 136

Material: A fragment of a dorsal valve from GSC 53900, Wahoo Formation, Malcolm River.

Fig. 136. *Spirifernaella* sp., fragment of dorsal valve GSC 140441, from GSC 53900, x3.

Description: The shell is transverse with alate cardinal extremities, a high slender fold with narrow crest, and two low plicae with well rounded crests to the side. Commarginal laminae cover most of the shell, which is impunctate. Internal plates have suffered breakage.

Superfamily **SPIRIFEROIDEA** King, 1846

Family **SPIRIFERIDAE** King, 1846

Subfamily **SPIRIFERELARIINAE** Waterhouse, 2016

Genus ***Tegulispirifer*** Poletaev, 2000

Diagnosis: Medium-sized to large transverse shells with extended hinge and well developed costate plicae, micro-ornament with strong commarginal laminae where well preserved, and fine radial capillae. Stegidial cover, small umbonal callosity and connector plate.

Type species: *Spirifer tegulatus* Trautschold, 1876, p. 354 from Moscovian (Middle Pennsylvanian) of Moscow Basin, Russia, OD.

Tegulispirifer? sp.

Fig. 137, 138

1971 *Neospirifer* sp. Bamber & Waterhouse, p. 120, pl. 2, fig. 15.

Material: Three ventral valves from GSC 53880, Barn Mountains. The posterior portion of four dorsal valves and fragments come from GSC 53899, and an obscure dorsal internal mould from GSC 53903. Both from Malcolm River, Wahoo Group, Lisburne Group.

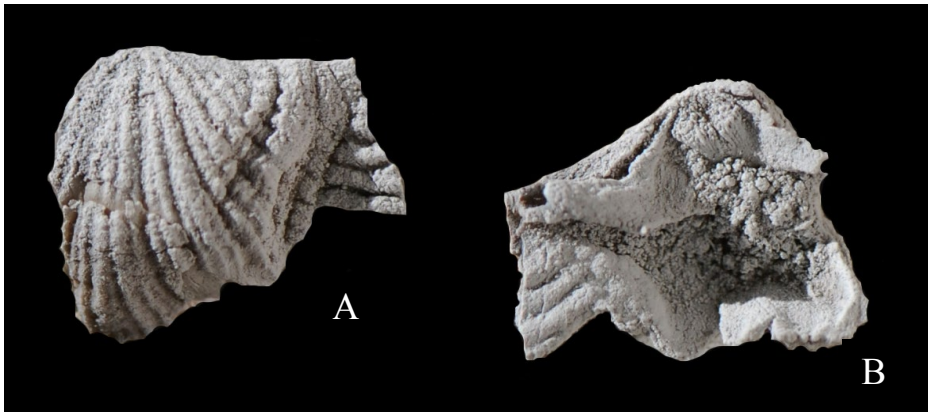


Fig. 137. *Tegulispirifer*? sp. A, B, external and internal aspects of dorsal fragment GSC 140445 from GSC 53899, x6.

Description: Only small fragments are available. Plicae are few and moderately well developed, and costae distinctive. A connector plate lies between the junction of the dental plates and adminicula, and secondary thickening lies between the posterior umbonal walls and plates. The dorsal valve has high crural plates and a ctenophoridium.

Resemblances: A closely ribbed and plicate small dorsal valve was recorded as *Neospirifer* sp. by Bamber & Waterhouse (1971) from GSC loc. 53973 at section 116F-9, Jungle Creek East, in the lower Ettrain Formation (Bamber 1972, p. 46; Waterhouse 1968c, p. 27).

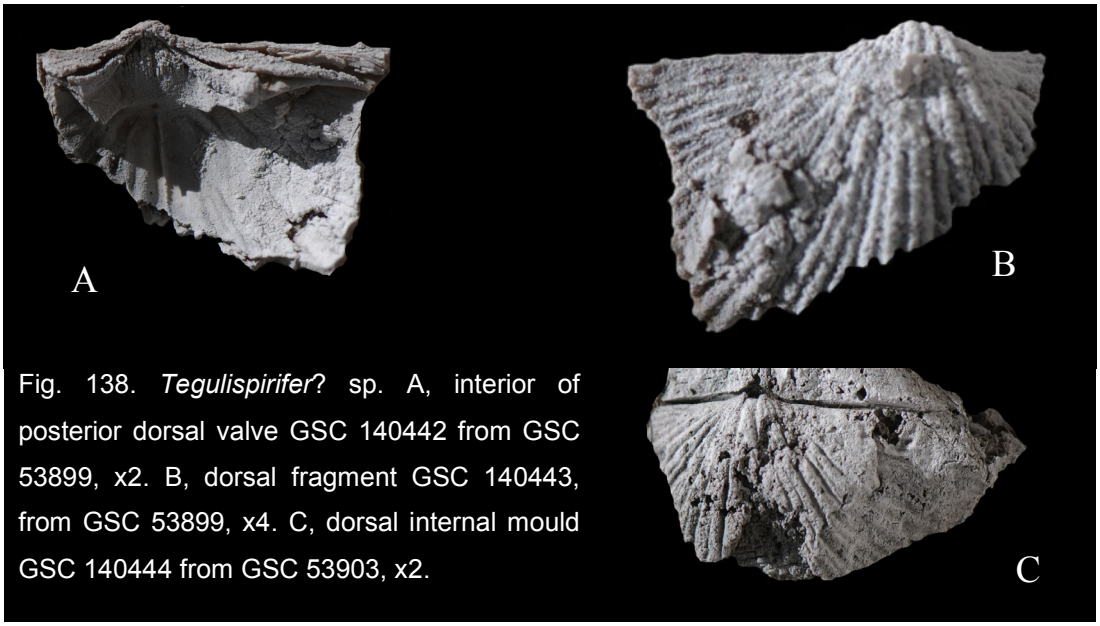


Fig. 138. *Tegulispirifer*? sp. A, interior of posterior dorsal valve GSC 140442 from GSC 53899, x2. B, dorsal fragment GSC 140443, from GSC 53899, x4. C, dorsal internal mould GSC 140444 from GSC 53903, x2.

Suborder DELTHYRIDINA Ivanova, 1972

Superfamily **ELITOIDEA** Fredericks, 1924

Family **PHRICODOTHYRIDAE** Caster, 1939

Genus ***Phricodothyris*** George, 1932

Phricodothyris sp.

Fig. 139

Material, Description: The fragment of a ventral valve from GSC 53925, Blackie Formation at Cathedral Rocks, shows a smooth shell bearing micro-ornament of spines, their nature unclear, in commarginal rows, and an interior with only low dental flanges along each side of an open delthyrium.

Fig. 139. *Phricodothyris* sp. ventral valve GSC 140446 from GSC 53925, x5. A small attached shell at the upper right might be *Hustedia*.

Order SPIRIFERINIDA Ivanova, 1972

Suborder SPIRIFERINIDINA Ivanova, 1972

Superfamily **PENNOSPIRIFERINOIDEA** Dagys, 1972

Discussion: At least two species are present, but the micro-ornament is so poorly preserved that identification even to family level is precarious, and one suite is set aside as too fragmentary and fragile.

Family **RETICULARIINIDAE** Waterhouse, 1975

Diagnosis: Transverse with fine plicae and well defined sulcus and fold; micro-ornament of coarse hollow spines over entire shell of both valves.

Genus ***Reticulariina*** Fredericks, 1916

Diagnosis: Transverse with fine plicae and well defined sulcus and fold; micro-ornament of coarse hollow spines over entire shell of both valves. Dorsal crural plates converge posteriorly to form a small plate.

Type species: *Spirifer spinosus* Norwood & Pratten, 1855, p. 71 from Chesterian of Illinois, United States, OD.

Discussion: Campbell (1959b) has provided excellent figures and description of the type specimens for this genus.

Reticulariina? sp.

Fig. 140

Material: Fragments of six ventral valves and three dorsal valves from GSC 53903, and six ventral valves and four dorsal valves, with other fragments, from GSC 53900. Malcolm River, Wahoo Formation, Lisburne Group. These specimens were silicified and are frail, very incomplete and decaying.

Description: Few specimens from GSC 53903 show much more than the median part of the shell, with lateral shell lost from most specimens. The half of a dorsal valve shows that the complete specimen was 14mm wide, nearly 9mm long and 4mm high, and a small incomplete ventral valve would have been 11mm wide, 6mm or more long and 2.5mm high. The largest fragments from GSC 53903 indicate ventral valves 14mm long and 6mm high. A broken specimen from GSC 53900 belonged to a specimen 15mm wide, 15mm long and 8mm high. The plicae number five pairs and suggestions of a sixth on the ventral valve, and five in number over the dorsal valve, and the inner pair next to the sulcus is high and narrow with narrowly rounded crests. Micro-ornament is very poorly preserved, but various parts of the shell on both valves unreliably suggest prominent erect hollow spines, up to three or four posteriorly and two anteriorly in 1mm. Growth laminae are prominent anteriorly.

Fig. 140. *Reticulariina?* sp., ventral valve GSC 140447 from GSC 53900, x3, twisted with the sulcus partly preserved to the left.

The dental plates are supported by short adminicula, with a median ventral septum extending for approximately half the length of the shell, and the delthyrium is open. Dental sockets are well developed in the dorsal valve, but further detail is obscure, although in one specimen the crural plates appear to merge with a median cardinal plate, supported by a low short median septum. In other specimens, the septum cannot be seen.

CORRELATION

The brachiopods belong to what was described as the B fauna in Bamber & Waterhouse (1971, pp. 122 ff). Only some of the brachiopods examined in that study are available for the present study, and the reader may refer to that account for a fuller analysis of the faunal sequence and thicknesses and occurrences. Some of the specimens figured in that study are larger than those now available, and being silicified, were judged too fragile to risk transport. One specimen not to have been duplicated amongst present collections is a dorsal valve identified as *Alispirifer*? from GSC 53880 (Bamber & Waterhouse 1971, pl. 3, fig. 7) in the Barn Mountains. *Alispirifer* Campbell, 1961 is of early Pennsylvanian (Bashkirian) age in east Australia. The illustration certainly suggests *Alispirifer*, but of course the identification needs to be verified.

In the Bamber & Waterhouse study, three distinct faunal levels or what may prove to be fossil communities were recognized. They were called zones in that article, a term requiring further assessment. The present survey lacks most of the material examined in that preliminary overview, so that whilst closer inspection has allowed the recognition of distinct and named taxa, the faunal distribution and succession are less amenable to study. A list of brachiopods from the basal level, recognized as an *Orthotichia* fauna, was reported as containing several species (see Bamber & Waterhouse 1971, p. 116), mostly not represented in the present collections, but including *Phricodothyris*. The material misidentified as *Orthotichia* is now judged to belong to *Rhipidomella*. The fauna ranged from high in Unit 2, now Blackie Formation, into the lower Ettrain Formation at its type section (116F-9) in the northern Ogilvie Mountains, as documented in Bamber (1972) for GSC locality 53957 (p. 50), GSC localities 53958 to 53960 (p. 49) and GSC 53961 (p. 48), with preliminary identifications outlined in Waterhouse (1968c, p. 28). Small Foraminifera were assessed as belonging to Zone 20 (Bashkirian) by Mamet in Bamber & Waterhouse (1971). Well dated Foraminifera of Zone 21 came from just above, judged to be late Bashkirian to early Moscovian in age, at GSC 53961. In some sequences, *Composita* is abundant and so-called *Orthotichia* (now *Rhipidomella*) was found to be rare, so a separate fauna was recognized, and considered to be correlative. *Composita* and questionable *Rorespirifer* were found in the Cathedral Rocks anticline section 116J-4A at GSC localities 53923 and GSC 53924, in what is now recognized as Blackie Formation. In the Malcolm River section (117C-2), *Rhipidomella* was reported as widespread in the Wahoo Formation at GSC 53899 to 53902, involving the species now identified as *Rhipidomella*

borealis n. sp., and in the Barn Mountains section (117A-15), *Composita* is found at GSC localities 53880 to GSC 53882 in the Wahoo Formation, with a linoproductid that may be *Protoanidanthus monstratus* n. sp. These localities are described on pp. 185 and 186 herein.

The topmost fauna, said to be distinguished by what is now called *Rorespirifer prodigium*, was found in the type Ettrain Formation in the Ogilvie Mountains, at section 116F-9, at GSC 53971, 53972, 53973 and GSC 53975 (Bamber & Waterhouse 1971, p. 119; Bamber 1972, p. 46), together with several other species, including *Rhipidomella, Composita* and a choristitid. *Rorespirifer* was also reported from the western Nahoni Range, at GSC localities 54008 and 54009 in section 116G-11 (Bamber 1972, pp. 91, 92), and the same species occurred in the Cathedral Rocks anticline in Unit 2, now Blackie Formation.

It is not possible to consolidate the separability of the three faunas then recognized, given that only some of the collections are now available. As in Bamber & Waterhouse (1971), a fauna readily distinguished from those of the underlying Hart River Formation, and older Blackie Formation at Peel River is present in at least some outcrops of the upper Blackie Formation, and in the Wahoo Formation, and in the lower type Ettrain Formation, although no comparable faunas have been found as far as can be determined in Ettrain equivalents, as reinterpreted. According to Bamber & Waterhouse (1971, p. 52), some 255ft of poorly exposed beds along the Peel River in section 116H-1B above what was classed as Unit 2, now Blackie Formation, also were deemed likely to belong to Unit 2, with Ettrain equivalents commencing with an overlying band of limestone. At GSC 53731, some 259ft above the base, or with that caution in mind, 4ft above the base, the lowest faunas from Ettrain equivalents contain faunas allied to those of the *Buxtonia sulcata* Zone in the underlying Blackie Formation, with genera such as *Umboanctus* and *Deltachania*, together with genera closer to those of younger Ettrain faunas, involving *Praehorridona, Gemmuliconcha*, *Waagenoconcha*, and aff. *Reticulatia,* and these faunas, without *Buxtonia*, *Umboanctus* and, as far as known, *Deltachania*, persist with an overall similarity, dominated by genera common in Russian faunas, through the Ettrain Formation and the overlying Jungle Creek Formation into beds as young as lower Artinskian (Nazer 1978, Shi & Waterhouse 1996, Waterhouse 2018). It would appear that some critical genera introduced in the *Buxtonia sulcata* Zone persisted well into Permian time.

The overall faunas were correlated on the basis of small Foraminifera examined by Mamet in Mamet & Ross (1971) with late Bashkirian to early up to mid-Moscovian, involving Foraminiferal

zones 20 through to 22, with the uppermost zone found in the beds with *Rorespirifer prodigium*, found in several sequences, and Ross (1967, p. 713) assigned Fusulinoidea from beds with *R. prodigium* faunas to a probable Moscovian age. In the northern Ogilvie Mountains, palynomorph subzones were recognized in the Blackie Formation (Bamber et al. 1989), a lower *Potonieisporites elegans* Assemblage subzone of Bashkirian age in the lower Blackie Formation, a *P. magnus* Assemblage subzone of late Bashkirian-early Moscovian age in the overlying Blackie Formation, and a *P. novicus* Assemblage subzone of Moscovian age in the middle and upper Blackie Formation. The exact match with the palynomorph localities with those of the brachiopods is not known to me. The Blackie Formation in this area is time-transgressive, and units extend through Moscovian and younger time, as illustrated by Bamber et al. (1989, Fig. 2). Upper Bashkirian Fusulines have been described from the Wahoo Formation of the British Mountains by Ross (1967). These assessments based on different fossil groups imply some discrepancies over age, and here major weight is placed on the data provided by small Foraminifera.

It is judged that *Rorespirifer* was a member of Ingelarellidae, a family particularly common in cool to cold-water faunas of especially north-east Russia and east Australia, particularly during Permian time, and its occurrence in northern Canada signified a significant cooling episode, quite likely to have been world-wide, although the particular international age remains somewhat imprecise at present for Gondwanan faunas likely to have been correlative. The other brachiopods appear, in our present state of knowledge, to offer no definite correlation, at least partly due to the apparent development of a distinct faunal province in northern Canada that became marked during this particular time interval, with development away from that prevalent in the United States, and becoming strongly influenced by faunas incoming from Russia.

***Rorespirifer prodigium* biozone**

The biozone is named after *Rorespirifer prodigium* n. sp., as the most striking species of the fauna so far known. Other common genera belong to *Protoanidanthus, Rhipidomella* and *Composita*, as well as choristitoid and purdonellid species.

SUMMARY OF FOSSIL LOCALITIES

GSC locality data for fossils described in the sections of the text on Systematic Descriptions

Quadralosia delicata Zone, Hart River Formation

Some detail of the fossil localities for the Hart River Formation are provided in Bamber & Waterhouse (1971, p. 243), and especially Bamber (1972, pp. 109. 110). There is limited information on GSC 53748 and 53749. They were collected by E. W. Bamber in 1962, though they do not seem to have been recorded in Bamber (1972), but they are listed as coming from Palmer Lake in Waterhouse (1968d, p. 14).

The puzzle of GSC loc. 53690

GSC locality 53690 was listed in Bamber (1972, p. 99) from the lower Ettrain equivalents of the Peel River west section 116H-1A, to imply it was much younger than outcrops of the Hart River Formation, and overlay rocks of the Blackie Formation. But the collection numbered GSC 53690 contains four species that indicate Hart River Formation, namely *Orbiculoidea* sp., *Praehorridonia* sp. which differs from younger species assigned to *Bailliena*, "*Kutorginella" primigenius* n. sp., and *Rhynchoporusia multiplicata* n. gen., n. sp., all pointing to the *Quadralosia delicata* Zone. If the fossils have not been egregiously misidentified, then the fossil locality has been misplaced, or there has been tectonic complication. Or there may have been a mistake in numbering the collection, because the faunal list differs considerably that noted for GSC 53690 in Waterhouse (1968d, p. 11). This seems to be the most likely explanation, but I do not have any material from the genuine GSC locality 53690.

Buxtonia sulcata Zone, Blackie Formation

The fauna was collected along the Peel River, on the side opposite to the rocks designated Cb in Bamber & Waterhouse (1971, Fig. 5), and repeated in Waterhouse & Waddington (1982, Fig. 4).

JBW 200 - Section 116H-1B, 60ft above top of Unit 2, revised to be within Unit 2, now Blackie Formation.

JBW 201 - Section 116H-1B, approximately 290ft above top of Unit 2, since revised to be within Unit 2, now Blackie Formation.

Rorespirifer prodigium Zone

Wahoo Fomation

GSC 53880 - Barn Mountains traverse, plants, 67°57'/136°08', collected by E. W. Bamber, 1962. See Bamber & Waterhouse 1971, p. 244.

GSC 53882 - Barn Mountains traverse at 15ft., talus; 67°57'/136°08', collected by E. W. Bamber, 1962.

GSC 53899 - Map 117C-5, Malcolm River section 117C-2, collected by E. W. Bamber, 1962. See Bamber 1972, p. 160.

GSC 53900 - Map 117C-5, Malcolm River section 117C-2 at 85 ft., 69°23'/140°35', collected by E. W. Bamber, 1962. See Bamber 1972, p. 160.

GSC 53901 - Map 117C-5, Malcolm River section at 85 ft., 69°23'/140°35', collected by E. W. Bamber, 1962. See Bamber 1972, p. 160.

GSC 53902 - Map 117C-5, Malcolm River section 117C-2 at 85 ft., 69°23'/140°35', collected by E. W. Bamber, 1962. See Bamber 1972, p. 160.

GSC 53903 - Map 117C-5, Malcolm River section at 283 ft., 69°23'/ 140°35', collected by E. W. Bamber, 1962. See Bamber 1972, p. 160.

Blackie Formation

GSC 53923 - Section 116J-4A, Cathedral Rocks, see Bamber & Waterhouse (1971, p. 244) and Bamber (1972, p. 123). Unit 2, now Blackie Formation.

GSC 53924 - Section 116J-4A, Cathedral Rocks, see Bamber & Waterhouse (1971, p. 244) and Bamber (1972, p. 123). Unit 2, now Blackie Formation.

GSC 53925 - Section 116J-4A, Cathedral Rocks, see Bamber & Waterhouse (1971, p. 244) and Bamber (1972, p. 123). Unit 2, now Blackie Formation.

Ettrain Formation

GSC 54008 – Section 116G-11, West Nahoni Range. See Bamber (1972, p. 91).

GSC 54009 – Section 116G-11, West Nahoni Range. See Bamber (1972, p. 92).

REFERENCES

ABRAMOV, B. C. 1965: Lower Carboniferous brachiopods from Cette Dabana. *In* Paleontology and biostratigraphy of Paleozoic and Triassic beds of Yakutin. M. Izd-vo Nauka. [Russ.]

_____ 1970: Biostratigraphy of the Carboniferous beds of Cette Davan (south Verchoyan). Izdatel. Nauka, Moscow: 170p. [Russ.]

_____ 1974: Stratigraphy of the Upper Paleozoic beds of South Verchoyan. Akad. Nauk. SSSR, Sibir. Otdel Yakutsk Fil. Geol. Inst.: 94p. [Russ.]

ABRAMOV, B. G., GRIGORIEVA, A. D. 1983: Biostratigraphy and Brachiopoda from Middle and Late Carboniferous of Verchoyan. Trudy Paleont. Inst. 200: 1-168, 32pl. [Russ.]

AHFELD, F., BRANISA, L. 1960: Geología de Bolivia: 245p., 12pl. Don Bosco, La Paz.

AISENBERG, D. E. 1962: On lower Visean brachiopod fauna from the Donets Basin. *In* Materielien der Fauna des oberen Paläozoikums im Donez-Kohlenbecken (Donbass). Teil 1. Vig. d. Akad. Wiss. Ukrain. SSR : 95-112, 6pl. [Russ.]

AISENBERG, D. E., ASTACHOVA, T. B., BERCHENKO, O. I. 1983: Upper Serpukhovian Substage in the Donets Basin. Akad. Sci. Ukrainian SSR. Inst. Geol. Sci.: 183p., 88pl. [Russ.]

ALEKSEEV, A. S., GOREVA, N. V., ISAKOVA, T. N., MAKHLINA, M. K. 2004: Biostratigraphy of the Carboniferous in the Moscow Syneclise, Russia. Newsletter on Carboniferous stratigraphy 22: 28-35, fig. 1.

ALVAREZ, F., BRIME, C., CURRY, G. B. 1987: Growth and function of the micro-frills present on the Devonian brachiopod *Athyris campomenesi* (Verneuil & Archiac). Proc. Roy. Soc. Edinburgh: Earth Sci. 78: 65-72.

ALVAREZ, F., RONG JIA-YU 2002: Athyridida. *In* R. L. Kaesler (ed.) Treatise on Invertebrate Paleontology, Part H, Brachiopoda revised, vol. 4, Rhynchonelliformea part: 1475-1583. Geol. Soc. Amer., Univ. Kansas; Boulder, Colorado & Lawrence, Kansas.

ARCHBOLD, N. W., THOMAS, G. A. 1985: New genera of Western Australian Permian Spiriferidae (Brachiopoda). Alcheringa 9: 269-292.

ARMSTRONG, A. K. 1958: The Mississippian of west-central New Mexico. Mem. New Mexico Inst. Mining & Technology, State Bureau Mines & Mineral Res. 5: 1-32, + unno. pp., 6pl.

_____ 1962: Stratigraphy and Paleontology of the Mississippian System in southwestern New Mexico and adjacent southeastern Arizona. Mem. New Mexico Inst. Mining & Technology,

State Bureau Mines & Mineral Res.8: 1-99, 12pl.

BAMBER, E. W. 1972: Description of Carboniferous and Permian stratigraphic sections, northern Yukon Territory and northwestern District of Mackenzie (N. T. S. 106M; 116C, F, G, I, J, P; 117A, B, C). Geol. Surv. Canada Paper 72-19: 161pp.

BAMBER, E. W., HENDERSON, C. M., JERZYKIEWICZ, J., MAMET, B. L., UTTING, J. 1989: A summary of Carboniferous and Permian biostratigraphy, northern Yukon Territory and northwest District of Mackenzie. *In* Current Research, Part G. Geol. Surv. Canada Pap. 89-1G: 13-21.

BAMBER, E. W., TAYLOR, G. C., PROCTER, R. M. 1968: Carboniferous and Permian stratigraphy of northeastern British Columbia. Geol. Surv. Canada Pap. 68-15: i-v, 1-25.

BAMBER, E. W., WATERHOUSE, J. B. 1971: Carboniferous and Permian stratigraphy and paleontology, northern Yukon Territory, Canada. Bull. Canadian Petrol. Geologists 19 (1): 29-250.

BARCHATOVA, V. P. 1968: *Spiriferella, Timaniella, Parachoristites*. *In* New species of ancient plants and invertebrates in the USSR. VSEGEI Izdvo “Nedra’, Moscow: 160-162, pl. 46, 47. [Russ.]

BEEDE, J. W. 1911: The Carbonic fauna of the Magdalen islands. New York State Mus. Bull. 149: 156-186.

BELL, W. A. 1929: Horton-Windsor district, Nova Scotia. Mem. Geol. Surv. Canada 155: 1-268, 36pl.

BENEDETTO, G. A. 1980: Sintesis biostatigrafica del Neopaleozoico tardio de los Andes de Venezuela. An. Acad. Brasil Ciec. 52 (4): 841-850.

BENEDIKTOVA, R. N. 1956: Spiriferids from the Kuzbass Suite. Questions of Geol. Kuzbass, T. 1. Mat. Btor. Svesh. Strat. Yuglen. beds. [Russ.]

BESNOSSOVA, G. A., 1968: Rhipidomellidae [part]. *In* Sarytcheva, T. G. Upper Paleozoic Brachiopoda from west Kazakhstan. Trudy Paleont. Inst. 121: 51, 52, pl. 1 [part]. [Russ.]

BOUCOT, A. J., JOHNSON, J. G., STATON, R. D. 1964: On some atrypoid, retzioid and athyridoid Brachiopoda. J. Paleont. 38: 805-822, pl. 125-128.

BOWSHER, A. L., DUTRO, J. T. 1957: The Paleozoic section in the Shainin Lake area, central Brooks Range, Alaska. U. S. Geol. Surv. Prof. Paper 303A.

BRABB, E. E. 1969: Six new Paleozoic and Mesozoic formations in east-central Alaska. U. S. Geol. Surv. Bull. 1274-1.

BRANISA, L. 1965: Los fósiles guias de Bolivia, 1 Paleozoico. Bol. Serv. Geol. Bolivia 6: 1-282, 80pl.

BREW, D. C., BEUS, S. S. 1976: A middle Pennsylvanian fauna from the Naco Formation near Kohl Ranch, central Arizona. J. Paleont. 50: 888-906, 2pl.

BRONN, H. G. 1862: Die Klassen und Ordnungen der Weichthiere (Malacazoa) vol. 3 (1): 518pp., 44pl. C. F. Winter'sche Verlagshandlung. Leipzig & Heidelberg.

BROWN, I. A. 1953: *Martiniopsis* Waagen from the Salt Range, India [sic]. J. Proc. Roy. Soc. New South Wales 86: 100-107.

BROWN, T. 1837-1849: Illustrations of the fossil conchology of Great Britain and Ireland: viii + 273pp., 98pl.

BRUNTON, C. H. C. 1966: Silicified productoids from the Visean of County Fermanagh. Bull. Brit. Mus. (Nat. Hist.) Geol. 12 (5): 155-243.

_____ 1968: Silicified brachiopods from the Visean of County Fermanagh (11). Bull. Brit. Mus. (Nat. Hist.) Geol. 16 (1): 1-70, 12pl.

_____ 1971: An endopunctate rhynchonellid brachiopod from the Visean of Belgium and Britain. Palaeontology 14: 95-106, 2pl.

_____ 1984: Silicified brachiopods from the Viséan of County Fermanagh, Ireland (111). Rhynchonellids, Spiriferids and Terebratulids. Bull. Brit. Mus. Nat. Hist. Geol. 38 (2): 27-130.

BRUNTON, C. H. C., LAZAREV, S. S., GRANT, R. E. 1995: A review and new classification of the brachiopod order Productida. Palaeontology 38: 915-936.

BRUNTON, C. H. C., LAZAREV, S. S., GRANT, R. E., JIN YUGAN 2000: Productidina. *In* R. L. Kaesler (ed.) Treatise on Invertebrate Paleontology, Part H, Brachiopoda revised, vol. 3, Linguliformea, Craniiformea, and Rhynchonelliformea part: 424-609. [Includes Strophalosiidina]. [Also] "Uncertain": 642-643. Geol. Soc. Amer., Univ. Kansas, Boulder; Colorado & Lawrence, Kansas.

CAMPBELL, K. S. W. 1956: Some Carboniferous productid brachiopods from New South Wales. J. Paleont. 30: 463-480, pl. 48-50.

_____ 1957: Lower Carboniferous brachiopod-coral fauna from New South Wales. J. Paleont. 31: 34-98.

_____ 1959a: The *Martiniopsis*-like spiriferids of the Queensland Permian. Palaeontology 1: 333-350.

_____ 1959b: The type species of three Upper Palaeozoic punctate spiriferoids. Palaeontology 1:

351-363, pl. 58, 59.

_____ 1961: Carboniferous fossils from the Kuttung rocks of New South Wales. Palaeontology 4: 428-474.

_____1966: The generic affinities of the brachiopod *Acanthatia*? *rangariensis* Campbell. J. Geol. Soc. Aust. 13 (1): 313.

CARTER, J. L. 1967: Mississippian brachiopods from the Chappel Limestone of central Texas. Bull. Amer. Paleont. 53 (238): 253-488, pl. 13-45.

_____ 1988: Lower Carboniferous brachiopods from the Banff Formation of western Alberta. Bull. Geol. Surv. Canada 378: 1-183, 29pl.

_____ 1990a: New brachiopods (Brachiopoda, Articulata) from the late Osagean of the Upper Mississippian valley. Ann. Carnegie Mus. 59 (3): 219-247, Fig. 1-11.

_____ 1990b: Subdivision of the lower Carboniferous in North America by means of Articulate brachiopod generic ranges. Courier Forsch. Inst. Senckenberg 130: 145-155.

_____ 1999: Tournaisian (early Osagean) brachiopods from a bioherm in the St Joe Formation near Kenwood, Oklahoma. Ann. Carnegie Mus. 68 (2): 91-149.

CARTER, J. L., GOURVENNEC, R. 2006: Martinioidea. *In* R. L. Kaesler (ed.) Treatise on Invertebrate Paleontology, Part H, Brachiopoda revised, vol. 5, Rhynchonelliformea (part): 1747-1768. Geol. Soc. Amer., Univ. Kansas; Boulder, Colorado & Lawrence, Kansas.

CARTER, J. L., JOHNSON, J. G., GOURVENNEC, R., HOU HONG-FE 1994: A revised classification of the spiriferid brachiopods. Ann. Carnegie Mus**.** 63 (4): 327-374.

CARTER, J. L., POLETAEV, V. I. 1998: Atokan (Late Bashkirian or Early Moscovian) brachiopods from the Hare Fiord Formation of Ellesmere Island, Canadian Arctic Archipelago. Ann. Carnegie Mus. 67 (2): 105-180.

CASTER, K. E. 1939: A Devonian fauna from Colombia. Bull. Amer. Paleont. 24 (83): 1-218, pl. 1-14.

CÉSARI, S. N., LIMARINO, C. O., GULBRANSON, E. L. 2011: An Upper Paleozoic bio-chronostratigraphic scheme for the western margin of Gondwana. Earth-Science Reviews 106 (2011): 149-160.

CHAO, Y. T. 1927a: Brachiopod fauna of the Chihsia Limestone. Bull. Geol. Soc. China 6 (2): 83-112.

_____ 1927b: Productidae of China. Pt 1. Producti. Palaeont. Sinica (ser. B) 5 (2).

_____ 1928: Productidae of China. Part 11, Chonetinae, Productinae and Richthofeniinae. Palaeont. Sinica (ser. B) 5 (3).

CHEN, Z-Q. 2004: Devonian-Carboniferous brachiopod zonation in the Tarim Basin, northwest China: implications for biostratigraphy and biogeography. Geol. J. 39: 431-458.

CHEN, Z-Q., SHI, G. R. 2003: Early Carboniferous brachiopod faunas and their biogeographical affinities from the western Kunlun Mountains, North-west China. Palaeontographica A 268 (4-6): 103-187, 12pl.

CISTERNA, G. A., ARCHBOLD, N. W. 2007: Spiriferoidea (Brachiopoda) from the early Permian Del Salto Formation of Argentina. Alcheringa 31 (1): 3-16.

COOPER, G. A., 1972: Correction of a brachiopod name. J. Paleont. 46: 450.

COOPER, G. A., GRANT, R. E. 1974: Permian brachiopods of west Texas 11. Smithson. Contrib. Paleobiol. 15.

_____ , _____ 1975: Permian brachiopods of west Texas 111. Smithson. Contrib. Paleobiol. 19.

_____ , _____ 1976: Permian brachiopods of west Texas V. Smithson. Contrib. Paleobiol. 24.

COOPER, G. A., DUTRO, J. T. 1982: Devonian brachiopods of New Mexico. Bull. Amer. Paleont. 82-83 (315): 1-215, 45pl.

COOPER, G. A., MUIR-WOOD, H. M. 1951: Brachiopod homonyms. J. Washington Acad. Sci. 41: 195-196.

_____ , _____1967: New names for brachiopod homonyms. J. Paleont. 41: 808.

COOPER, G. A., WILLIAMS, J. S. 1935: Tully Formation of New York. Geol. Soc. Amer. Bull. 4: 781-868, pl. 57-60.

DAGYS, A. S. 1972: The occurrence of a Metachoresa in a Triassic spiriferid. *In* Problems of Paleozoogeography in the Mesozoic of Siberia. Acad. Nauk. SSSR, Sibir. Otdel. Inst. Geol. Geofiz. Trudy 111: 34-44, 4 fig. [Russ.]

DAVIDSON, T. 1848: Mémoire sur les Brachiopodes du Système Silurien supérieur de l'Angleterre. Bull. Soc. Géol. France (ser. 2) 5: 309-338, 370-374, 2pl.

_____ 1880: Supplement to the British Carboniferous Brachiopoda. Palaeontographical Society 4: 249-313, pl. 30-37.

_____ 1881: On genera and species of spiral-bearing Brachiopoda from specimens developed by

Rev. Norman Glass: with notes on the results obtained by Mr. George Maw from extensive washing of the Wenlock and Ludlow shales of Shropshire. Geol. Mag. (n. s., dec. 11) 8 (1): 1-13.

DERBY, G. A. 1874: On the Carboniferous brachiopods of Itaituba, Rio Tapajos, Province of Para, Brazil. Bull. Cornell Univ. Sci. 1 (2): 1-63, 9pl.

DIENER, C. 1903: Permian fossils of the central Himalayas. No. 1. Palaeont. Indica (ser. 15) 1 (2).

_____ 1915: The Anthracolithic Faunae of Kashmir, Kanaur and Spiti. Palaeont. Indica (n. s.) 5 (2): 1-135.

DUMÉRIL, A. M. C. 1806: Zoologie analytique ou méthode naturelle de classification des animaux: xxiv + 344pp. Allais. Paris

DUN, W. S. 1902: Description of a new species of *Productus* from the Carboniferous System of New South Wales. Rec. Geol. Surv. New South Wales 7 (1): 91-93, pl. 25.

DUNBAR, C. O., CONDRA, G. E. 1932: Brachiopoda of the Pennsylvanian System in Nebraska. Nebraska Geol. Surv. Bull. (ser. 2) 5: 1-377.

EASTON, W. H. 1942: The Pitkin Limestone of northern Arkansas. Arkansas Geol. Surv. Bull. 3: 115pp.

_____ 1943. The fauna of the Pitkin Formation of Arkansas. J. Paleont. 17: 125-154.

EINOR, O. L. 1939: Lower Permian brachiopods of Taimyr. Trans. Arctic Inst. Leningrad 135: 1-150, pl. 1-15. [Russ.]

ELIAS, M. K. 1957: Mississippian fauna from the Redoak Hollow Formation of southern Oklahoma. Part 11. Brachiopoda. J. Paleont. 31 (3): 487-527, pl. 51-58.

ENGEL, B. A. 1975: A new ?bryozoan from the Carboniferous of eastern Australia. Palaeontology 18: 571-605.

_____ 1980: Carboniferous biostratigraphy of the Hunter-Manning-Myall Province. Bull. Geol. Surv. New South Wales 16 (1): 317-360.

ERLANGER, O. A. 1993: *Greira* gen. nov., the oldest genus of punctate rhynchonellids. Paleont. Zhurn. 1993 (1): 118-122. [Russ.]

FREDERICKS, G. 1915: To the knowledge of the Upper Carboniferous and Artinskian *Productus*. Trudy Geol. Kom. n. s. 103: 1-63, 5pl. [Russ.]

_____ 1916: Paleontological Notes 2. On some Upper Paleozoic Brachiopoda of Eurasia. Trudy Geol. Kom. 156: 1-87. [Russ.]

_____ 1924: Paleontological Studies 2. On the Upper Carboniferous spiriferids from the Urals. Izvest. Geol. Kom. 38 (3): 295-324. (Published 1919).

_____ 1926: Matériaux se rapportant à la faune de l'assise sable-argileuse de la riv. Kejim-Terovey. Ann. Soc. Paléont. Russie 4: 80-92, 3pl. [Russ., Fr. summary]

_____ 1925: Upper Paleozoic of the Ussuriland, 11: Permian Brachiopoda of Cape Kalouzin. Materials Geol. Polez. Iskoraem. Dal. Vostok. 40: 1-30. [Russ.]

_____ 1927 (1928): Contribution to the classification of the genus *Productus* Sowerby. Izvest. Geol. Kom. 46 (7): 773-792. [Russ.]

GEHRIG, J. L. 1958: Middle Pennsylvanian brachiopods from the Mud Springs Mountains and Derry Hills, New Mexico. Mem. New Mexico Inst. Mining & Technology, State Bureau Mines & Mineral Res. 3.

GEORGE, T. N. 1931: *Ambocoelia* Hall and certain similar British Spiriferidae. Quart. J. Geol. Soc. London 87: 30-61, pl. 3-5.

_____ 1932: The British Carboniferous reticulate Spiriferidae. Quart. J. Geol. Soc. London 88 (4): 516-575, pl. 31-35.

GIRTY, G. H. 1899: Geology of the Yellowstone National Park, pt 2, sect. 2, Devonian and Carboniferous fossils. U. S. Geol. Surv. Mon. 32 (2): 479-599, pl. 56-71.

_____ 1910a: New genera and species of Carboniferous fossils from the Fayetteville Shale of Arkansas. New York Acad. Sci. Ann. 20, no. 3 (2): 189-238.

_____ 1910b: The fauna of the Phosphate Beds of the Park City Formation in Idaho, Wyoming and Utah. U. S. Geol. Surv. Bull. 436: 1-86, 7pl.

_____ 1911: The fauna of the Moorefield Shale of Arkansas. Bull. U. S. Geol. Surv. 439: 1-148, 15pl.

_____ 1915: Invertebrate paleontology. *In* HINDS, H. & GREENE, F. C. The stratigraphy of the Pennsylvanian series in Missouri. Missouri Bur. Geol. Mines (ser. 2) 13: 263-375.

_____ 1927: Descriptions of Carboniferous and Triassic fossils. *In* MANSFIELD, G. R. Geography, Geology and Mineral Resources of part of southeastern Idaho. Prof. Pap. U. S. Geol. Surv. 152: 411-446, pl. 22, 23, 27, 28.

_____1939: *Setigerites* nom. nov., a subgenus of *Productus*. J. Washington Acad. Sci. 29 (4): 141.

GONZALEZ, A. D. 1952: On the Carboniferous Brachiopoda of Itaituba, Rio Tapajos, Prov. of Para, Brazil. *In* Orville A. Derby's Studies on the Paleontology of Brazil: 23-95, 9pl. Brazil, Rio de Janeiro.

GORJANSKY, V. Yu, POPOV, I. E. 1985: Morphology, systematic position and origin of the inarticulate brachiopods with calcareous shells. Paleont. Zhurn. 1985 (3): 3-14, 1pl. [Russ.]

GRABAU, A. W. 1924: Stratigraphy of China, Part 1. Palaeozoic and older. Geol. Surv. China: 528pp., 6pl.

_____ 1927: In CHAO, Y. T. 1927a.

GRANT, R. E. 1976: Permian brachiopods from southern Thailand. Paleont. Soc. Memoir 9. Suppl. to J. Paleont. 50 (3): 1-269.

GRAY, J. E. 1840: Synopsis of the contents of the British Museum. 42nd edit. British Museum, London, 370pp.

GRIGORIEVA, A. D., SOLOMINA, R. V. 1973: A new genus of Licharewiinae (Brachiopoda) from the Permian of Verchoyn'ye and the northeast USSR. Paleont. Zhurn. 1973 (4): 35-39. [Russ.]

GRINNEL, R. S., ANDREWS, G. W. 1964: Morphologic studies of the brachiopod *Composita*. J. Paleont. 38: 227-247, pl. 37-39.

GRUNT, T. A. 1965: Superfamily Athyridacea. *In* V. E. Ruzencev & T. G. Sarytcheva (ed.) Evolution and change of marine organisms at the Paleozoic-Mesozoic boundary. Trudy Paleont. Inst. 108: 237-253. [Russ.]

_____ 2006: Order Spiriferida Kuhn, 1949. *In* Upper Permian of the Kanin Peninsula. Russian Acad. Sci., Urals Branch, Science Centre Inst. Geol.: 151-163. [Russ.]

GUPTA, V. J., WATERHOUSE, J. B., BHARGAVA, O. N. 1985: Indian subcontinent. *In* The Carboniferous of the World. Australia, Indian subcontinent, South Africa, South America & North Africa. Inst. Geol Minero Espana: 147-165, 5pl. IUGS Publication 20.

HALL, J. 1852: Geology and Paleontology. *In* Stansbury's Expl. and Survey of the Valley of the Great Salt Lake, Utah: 399-414, pl. 1-4. London.

____ 1858: *In* HALL J., WHITNEY J. D. Report on the Geological Survey…. of the State of Iowa: embracing the … results of investigations made during portions of the years 1855, -56 and -57. 1 (2): Palaeontology: 473-724.

_____ 1860: Contributions to the Palaeontology of New York: 1858 & 1859. Appendix. Part F, of the 13th Annual Report of the Regents of the University of the State of New York on the condition of the State Cabinet of Natural History, and the Historical and Antiquarian Collection annexed thereto. Albany: 53-125. Observations on genera of Brachiopoda, pp. 65-73, observations on the genera

Athyris (=*Spirigera*), *Merista* (=*Camarium*), *Meristella*, and *Leyeorhynchus*, pp. 73-75; descriptions of new species of fossils from the Hamilton group of western New York, with notices on others from the same horizon in Iowa and Indiana, pp. 76-94.

HALL, J. CLARKE, J. M. 1894: The evolution of the genera of Palaeozoic Brachiopoda. New York State Museum 47th Annual Report. Albany: 803-851, 943-1137.

____ , _____ 1895: An introduction to the study of the genera of Palaeozoic Brachiopoda. Natural History of New York, Palaeontology 8 (2): xvi + 394pp., pl. 21-84. Charles van Benthuysen & Sons, Albany.

HECKEL, P. H. 2004: Chairman's column. Newsletter on Carboniferous stratigraphy 22: 1-3, Fig. 1.

HENRY, T. W., SUTHERLAND, P. K. 1977: Brachiopod biostratigraphy of Morrowan Series (Pennsylvanian) in northwestern Arkansas and northeastern Oklahoma. Oklahoma Geol. Surv. Guidebook 18: 107-115, 2pl.

IVANOV, A. P. 1935: Brachiopods of the Middle and Upper Carboniferous of the Moscow Basin, part 1: Productidae Gray. Trudy Moscow Geol. Tresta: 1-163, 15pl. [Russ.]

IVANOVA, E. A. 1951: New data on productid systematics (genus *Kutorginella*). Comptes Rendus Acad. Sci. SSSR 77 (2): 329-331. [Russ.]

_____ 1972: Main features of spiriferid evolution (Brachiopoda). Paleont. Zhurn. 1975 (2): 28-42. [Russ.]

JOHNSON, J. G., CARTER, J. L., HOU HONG-FEI 2006. Ambocoelioidea. *In* R. L. Kaesler (ed.) Treatise on Invertebrate Paleontology, Part H, Brachiopoda revised, vol. 5, Rhynchonelliformea (part): 1733-1746. Geol. Soc. Amer., Univ. Kansas; Boulder, Colorado & Lawrence, Kansas.

KALASHNIKOV, N. V. 1974: Carboniferous Brachiopoda from the Petchora Urals. Akad. Nauk SSSR Kom. Fil. Inst. Geol. 1-166, 52pl. [Russ.]

_____ 1980: Brachiopods from the Upper Paleozoic from European part of north USSR. Akad. Nauk. SSSR, Kom. Fil. Inst. Geol. Leningrad: 1-136, 39pl. [Russ.]

KING, W. 1846: Remarks on certain genera belonging to the class Palliobranchiata. Ann. Mag. Nat. Hist. (ser. 1) 18: 26-42, 83-94.

_____ 1865: Remarks on the histology of two specimens of *Rhynchopora geinitziana* de Verneuil, from near the River Oukhla, Province of Archangel, and belonging to the collection of the Corps des Mines of St Petersburg. Ann. Mag. Nat. Hist. (ser. 3) 16: 124-128.

KLETS, A. G. 1983: A new Carboniferous productid genus. Paleont. Zhurn. 1983 (1): 74-78, 1pl. [Russ.]

_____ 2005: Upper Paleozoic of marginal seas of Angarida. Inst. Petrol. Geol. UIGGM SB – RAS, Novosibirsk: 1-242. [Russ.]

KONINCK, L. G. de 1843: Descriptions des animaux fossils: 241-280. Liège.

_____ 1887: Faune du Calcaire Carbonifère de la Belgique. Ann. Mus. Roy. Hist. Nat. Belg. 14: 1-154, pl. 1-37.

KOTLYAR, G. V. 1961: On genus *Yakovlevia* Frederiks. Doklady Akad. Nauk. SSSR 140 (2): 459-460. [Russ.]

KOTLYAR, G. V., POPEKO, L. I. 1967: Biostratigraphy of Bryozoa and Brachiopoda from the Upper Paleozoic of Zabaikal. Notes, Zabaikal. Branch, Geogr. Publ. SSR 28. Trudy Otdel. Geol. 5: 1-324, 57pl. [Russ.]

KOZLOWSKI, R. 1914: Les Brachiopodes du Carbonifère Supérieur de Bolivie. Ann. Paléont. 9.

_____ 1929: Les brachiopods gothlandiens de la Podolie polonaise. Palaeont. Polonica 1: 1-254, pl. 1-2.

KUHN, O. 1949: Lehrbuch der Paläozoologie. v + 326pp. E. Schweizerbart'sche Verlagsbuchhandlung. Stuttgart.

LANE, B. O. 1962: The fauna of the Ely Group in the Illipah area of Nevada. J. Paleont. 36: 888-911, pl. 125-128.

LAZAREV, S. S. 1985: Brachiopods of the Families Echinoconchidae and Buxtoniidae. Paleont. Zhurn. 1985 (1): 64-74, pl. 5. [Russ.]

_____ 1989: Systematics of Devonian brachiopods of Suborder Strophalosiidina. Paleont. Zhurn. 1989 (2): 27-39, pl. 3. [Russ.]

_____ 1990: Evolution and systematics of the Productida. Trudy Paleont. Inst. 242. [Russ.]

_____ 1992: The evolution and systematics of the brachiopod Family Plicatiferidae. Paleont. Zhurn. 1992 (1): 44-52. [Russ.]

LÉVEILLÉ, C. 1835: Aperçu géologique de quelques localités très riches en coquilles sur les frontières de France et de Belgique. Mém. Soc. Géol. France: 2: 29-40, 2pl.

LIASHENKO, I. A. 1969: New Devonian brachiopods from the central and western areas of the Russian Platform. Trudy VNIGRI 93: 9-27, 5pl. [Russ.]

LICHAREW, B. K. 1925: Ueber einem neuen Vertreter der Fam. Lyttoniidae aus dem Obercarbon des Ural. Dokl. Akad. Nauk SSR (ser. A) 1925: 4-7.

_____ 1928a: Ueber einige seltene und neue Brachiopoden aus dem Unterperm des nordlichen Kaukasus. Paläont. Zeit. 10 (3): 258-289.

_____ 1928b: On some rare and new brachiopods from Lower Permian of north Caucasus. Bull. Com. Géol. 47 (3): 261-296, pl. 23, 24. [Russ.]

_____ 1938: Materials. Brachiopoda of Donbass. Geol. Journal AN Ukrainian SSR 5 (3): 73-129, 5pl. [Russ.]

_____ 1939: Brachiopoda. *In* I. Gorsky (ed.) Atlas of the leading forms of the fossil faunas of the SSSR, vol. 5 – Middle and Upper Carboniferous. Moscow: 79-113, pl. 16-28. [Russ.]

_____ 1947: On a new subgenus *Muirwoodia* of the genus *Productus* Sow. sensu lato. Akad. Nauk. SSSR, Doklady 57 (2): 187-190. [Russ.]

_____ 1956: Brachiopoda. *In* L. D. Kiparisova, B. P. Markovski, G. P. Badchenko (ed.) Min. Geol. Okhran. Nedr. Moscow 12 n.s. Paleont.: 52-53, 56-61, 64-70. [Russ.]

_____ 1960: Upper Paleozoic Rhynchonellida. *In* T. G. Sarytcheva (asst ed.) Bryozoa, Brachiopoda. Y. A. Orlov (ed.). Osnovy Paleontologii vol. 7: 239-257. Akad. Nauk SSSR, Moscow. [Russ.]

LICHAREW, B. K., EINOR, O. L. 1939: Materials for the study of the Upper Paleozoic faunas of Novaya Zemlya. Brachiopoda. Trudy Arktic Nauk. Issled. Inst. 127: 1-245, 25pl. [Russ.]

MAMET, B. L., BAMBER, E. W. 1979: Stratigraphic correlation chart of the lower part of the Carboniferous, Canadian Cordillera and Arctic Archipelago. V111th Internat. Congr. on Carboniferous Stratigraphy and Geology, Compe Rendu 3: 37-49. Nauka Pub. House, Moscow.

MAMET, B. L., SKIPP, B. A. 1970: Preliminary foraminiferal correlation of Early Carboniferous strata in the North American Cordillera. Colloque sur la Stratigraphie du Carbonifère. Les Congres et Colloques de Université de Liège 55: 327-428.

MAMET, B. L., ROSS, C. A. 1971: Foraminiferal microfacies of the Upper Paleozoic Northern Yukon Territory. *In* BAMBER, E. W. WATERHOUSE, J. B. Carboniferous and Permian stratigraphy and paleontology, northern Yukon Territory, Canada. Bull. Canadian Petrol. Geologists 19 (1): 196-205.

MANANKOV, I. N. 1979: Strophomenids of the Late Paleozoic of Siberia and the Arctic. Trudy Paleont. Inst. 171. [Russ.]

_____ 2008: *Mongousia*: a new productid genus (Brachiopoda) from the Permian of northeastern

Mongolia. Paleont. Zhurn. 2008 (3): 42-44. [Russ.]

MARTIN, W. 1809: Petrefacta derbiensia; or figures and descriptions of petrefactions collected in Derbyshire: 28pp., 52pl. Wigan, London.

MARTÍNEZ CHACÓN, M. L. 1979: Braquiopodos Carboniferos de la Cordillera Cantabrica (Orthida, Strophomenida y Rhynchonellida). Mem. Inst. Geol. Minero Espana: 1-291, 32pl.

MASLENNIKOV, D. F. 1960: New genera of Permian echinoconchids from Zabaikal. *In* B. P. Markowskii (ed.) New species of prehistoric plants and invertebrates of the USSR, part 1. VSEGEI: 341-343, pl. 81. Moscow. [Russ.]

MASSA, D., TERMIER, G., TERMIER, H. 1974: Le Carbonifère de Libye Occidentale. Stratigraphie et Paléontologie. Compag. Franc. des Pétroles. Notes et Mém. 11: 139-206, 12pl., 5 + 11 fig.

MATHER. K. F. 1915: The fauna of the Morrow Group of Arkansas and Oklahoma. Bull. Sci. Lab. Denison University 18: 59-250.

MAXWELL, W. G. H. 1951: Upper Devonian and Middle Carboniferous brachiopods of Queensland. Pap. Dep. Geol. Univ. Qld 3 (14): 1-27, 3pl.

_____ 1964: The geology of the Yarrol region. Part 1. Biostratigraphy. Pap. Dep. Geol. Univ. Qld 5 (9): 3-79.

McKELLAR, R. G. 1965: An Upper Carboniferous brachiopod fauna from the Monto district, Queensland. Publ. Geol. Surv. Qld 328: 1-15, 5pl.

_____ 1970: The Devonian productoid brachiopod faunas of Queensland. Geol. Surv. Queensland (Palaeont. Pap.) 342: 1-40, pl. 1-12.

MEEK, F. B., WORTHEN, A. H. 1862: Descriptions of new Palaeozoic fossils from Illinois and Iowa. Acad. Nat. Sci. Philadelphia, Proc. (ser. 2) 13: 128-148.

MENDES, J. C. 1956: Orthotetacea e Dalmanellacea do Carboniferous superior do rio Tapajos (série Itaituba). Bol. Soc. Bras. Geol. Geol. 5 (1): 11-38, pl. 1-4.

MIRONOVA, M. G. 1964: Contributions to the knowledge of Early Permian brachiopods of the Petchora Basin. Vopros. Paleont. 4: 85-99. [Russ.]

_____ 1967: Bashkirian brachiopods from Carboniferous beds. Leningrad Univ.: 1-64, 5pl. [Russ.]

MOORE, R. C. 1952: *In* MOORE, R. C., LALICKER, C. G., FISCHER, A. G. Invertebrate fossils: 766pp. McGraw-Hill, New York.

MUIR-WOOD, H. M. 1928: British Carboniferous Producti 2: *Productus* (s. s.), *semireticularis* and

longispinus groups. Mem. Great Brit. Geol. Surv. (Palaeontology) 3 (1): 1-217, 12pl.

_____ 1955: A history of the classification of the Phylum Brachiopoda. Brit. Mus. (Nat. Hist.), London: v + 124pp.

MUIR-WOOD, H. M., COOPER, G. A. 1960: Morphology, classification and life habits of the Productoidea (Brachiopoda). Geol. Soc. Amer. Mem. 81.

MURPHY, D. R. 1954: Fauna of the Morrowan rocks of central Utah. Brigham Young Univ. Res. Stud. Geol. (Ser. 1) 3: 1-64, 4pl.

NALIVKIN, D. V. 1979: Brachiopods from the Tournaisian Stage of the Urals. Akad. Nauk SSSR, Otdel. Geol. Geofiz. Geokhim. Nauka, Leningrad: 248pp., 65pl. [Russ.]

NASIKANOVA, O. N. 1968: Genus *Sajakella* Nasikanova, gen. nov. *In* Sarytcheva, T. G. (ed.) Brachiopoda from the Upper Paleozoic of western Kazakhstan. Trudy Paleont. Inst. 121: 141-142. [Russ.]

NAZER, R. E. 1977: Late Visean brachiopods with western Australian affinities from the Yarrol Shelf. Qld Govt Min. J. 78: 126-131.

_____ 1978: Late Carboniferous brachiopods from the Yukon Territory, Canada. Unpub. Ph. D. thesis, University of Queensland, Brisbane, 308pp., 38pl.

NELSON, S. J. 1961a: Permo-Carboniferous of the northern Yukon Territory. J. Alberta Soc. Petroleum Geologists 9 (1): 1-9, 4pl.

_____ 1961b: Mississippian faunas of western Canada. Geol. Assoc. Canada Spec. Pap. 2: 1-39, 29pl.

NELSON, S. J., JOHNSON, C. E. 1968: Permo-Pennsylvanian brachythyrid and horridonid [sic] brachiopods from the Yukon Territory, Canada. J. Paleont. 42: 715-746.

NORRIS, D. K. (ed.) 1997: Geology and Mineral and Hydrocarbon potential of northern Yukon Territory and northwestern District of Mackenzie. Geol. Surv. Canada Bull. 422: 1-401.

NORWOOD, J. G., PRATTEN, H. 1855: Notice of fossils from the Carboniferous Series of the western states, belonging to the genera *Spirifer, Bellerophon, Pleurotomaria, Macrocheilus, Natica* and *Loxonema*, with descriptions of eight new characteristic species. J. Acad. Nat. Sci. Philadelphia (ser. 2) 3: 71-77.

OEHLERT, D. P. 1890: Note sur différents groups établis dans le genre *Orthis* et en particulier sur *Rhipidomella* Oehlert (= *Rhipidomys* Oehlert, olim). J. Conchyliogie 30: 366-374.

ÖPIK, A. A. 1934: Ueber Klitamboniten. Univ. Tartuensis (Dorpatensis) Acta et Comment. (ser. A) 26 (5): 1-239, pl. 1-48.

ORBIGNY, d' A. 1842: Voyages dans l'Amérique méridionale. Vol 3, Paléont.: 50-56, pl. 3-5. Pitois-Levrault et cie, Paris.

PAECKELMANN, W. 1931: Die Fauna des deutschen Unterkarbons. Die Brachiopoden, 2 Teil: Die Productinae und Productus-ähnlichen Chonetinae. König. Preuss. Geol. Landes. Abh. (n. s.) 122: 3-440, pl. 1-41,

PAVLOVA, E. E., DURANTE, M. V., MANANKOV, I. N., TOMURTOGOO, O., ASTAFIEVA-URBAITIS, K. A. 1983: Carboniferous beds from Deng-Nuri in southern Mongolia and observations on biostratigraphy and palaeogeography on the Carboniferous of central Asia. *In* New species of fossil invertebrates of Mongolia. The joint Soviet-Mongolian Paleontological Expedition Trans. 20: 73-80. [Russ.]

PHILLIPS, J. 1836: Illustrations of the geology of Yorkshire: Part 2, the Mountain Limestone district: 253pp., 25pl. John Murray, London.

POLETAEV, V. I. 1986: Choristitid brachiopods of the family Spiriferidae. Paleont. Zhurn. 1986 (3): 60-72. [Russ.]

_____ 2000: *Donispirifer* and *Tegulispirifer* – new Middle to Late Carboniferous spiriferids from Eurasia. Paleont. Zhurn. 2000 (3): 50-57. [Russ.]

PUGH, D. C. 1983: Pre-Mesozoic geology in the subsurface of Peel River map area, Yukon Territory and District of Mackenzie. Geol. Surv. Canada Mem. 401: 1-61.

REED, F. R. C. 1943: Notes on certain Upper Devonian brachiopods figured by Whidborne, part 1-2. Geol. Mag. 80: 69-78, 95-106.

_____ 1944: Brachiopoda and Mollusca from the Productus Limestones of the Salt Range. Palaeont. Indica (n. s.) 23 (2): 1-678, 65pl.

_____ 1948: Notes on some Carboniferous Spiriferidae from Fife. Ann. Mag. Nat. Hist. (ser. 12) 1: 449-484, 12pl.

ROBERTS, J. 1964: Lower Carboniferous brachiopods from Greenhills, New South Wales. J. Geol. Soc. Aust. 11: 173-194, pl. 1-6.

_____ 1971: Devonian and Carboniferous brachiopods from the Bonaparte Gulf Basin, northwestern Australia. Bull. Bureau Mineral Res. Geol. Geophys. 122: xiii + 319pp., 59pl.

_____ 1981: Control mechanisms of Carboniferous brachiopod zones in eastern Australia. Lethaia 14: 123-134.

_____ 1985: Faunas and floras. Brachiopods. *In* Australia. The Carboniferous of the World. Australia, Indian subcontinent, South Africa, South America & North Africa. Inst. Geol Minero Espana: 105-108. IUGS Publication 20.

ROBERTS, J., CLOUE-LONG, J. C., JONES, P. J., FOSTER, C. B. 1995: SHRIMP zircon age control of Gondwana sequences in Late Carboniferous and Early Permian Australia. *In* R. E. Dunay, E. A. Hailwood (ed.) Non-biostratigraphical methods of dating and correlation. Geol. Soc. London Spec. Publ. 89: 145-174.

ROBERTS, J., HUNT, J. W., THOMPSON, D. M. 1976: Late Carboniferous marine invertebrate zones of eastern Australia. Alcheringa 1: 197-225.

ROCHA-CAMPOS, A. C., ARCHANGELSKY, S. 1985: South America. *In* The Carboniferous of the World. Australia, Indian subcontinent, South Africa, South America & North Africa. Inst. Geol Minero Espana: 175-270, 13pl. IUGS Publication 20.

ROSS, C. A. 1967: Late Paleozoic Fusulinacea from northern Yukon Territory. J. Paleont. 41: 709-725, pl. 79-86.

_____ 1969: Upper Paleozoic Fusulineacea from northern Yukon Territory and giant *Parafusulina* from British Columbia. Geol. Surv. Canada Bull. 182: 129-134.

ROTAI, A. P. 1931: Brachiopods and stratigraphy of the Lower Carboniferous of the Donets Basin. M. D. Trudy GT. G. Ukraine 73: 1-144. [Russ.]

_____ 1939: Upper Carboniferous from the Donets Basin and likely Namurian Stage of the coal-mining system. V. Kh. Trudy 17 Ses. Mezpunar. Geol. Kontr. M. GONTI 1: 465-478. [Russ.]

_____ 1951: Middle Carboniferous of the Donets Basin. Part 1. Spiriferidae. VSEGEI Minist. Geol.: 1-132, 24pl. [Russ.]

ROWLEY, R. R. 1900: Descriptions of new species of fossils from the Devonian and sub-Carboniferous rocks of Missouri. Amer. Geol. 25: 261-273.

ROZANOV, A. Y. (ed.) 2003: Paleontology of Mongolia. Brachiopoda. Russ. Akad. Nauk. Paleont. Inst., 2003 Izdatel. Sci. Mongol. [Russ.]

SAMTLEBEN, C. 1971: Zur Kenntnis der Produktiden und Spiriferiden des bolivianischen Unterperms. Beih. Geol. Jb 111: 1-163, 11pl.

SARKAR, S. S. 1965: Catagenesis in a series of *Productus* from the Liddar Valley in Kashmir. Paläont. Zeit. 39 (1/3): 94-98.

SARTENAER, P. 1964: Refonte du genre *Pugnoides* Weller, S. 1910 (Rhynchonelloidea). Inst. Roy. Sci. Natur. Belgique Bull. 40 (12): 1-10, 2pl.

SARYTCHEVA, T. G. 1952: See SARYTCHEVA, T. G., SOKOLSKAYA, A. N. 1952.

_____ (asst. ed.) 1960: Bryozoa, Brachiopoda. Y. A. Orlov (ed.) Osnovy Paleontologii, vol. 7. Acad. Nauk. SSSR, Moscow. [Russ.]

_____ (ed.) 1968: Upper Paleozoic brachiopods from Kazakhstan. Trudy Paleont. Inst. 121. [Russ.]

_____ (ed.) 1977a: Upper Paleozoic productids of Siberia and the Arctic. Trudy Paleont. Inst. 161. [Russ.]

_____ (ed.) 1977b: Upper Paleozoic brachiopods of Siberia and the Arctic. Trudy Paleont. Inst. 162. [Russ.]

SARYTCHEVA, T. G., LICHAREW, B. K., SOKOLSKAYA, A. N. 1960: Order Productida. *In* T. G. Sarytcheva (asst. ed.) Bryozoa, Brachiopoda. Y. A. Orlov (ed.) Osnovy Paleontologii, vol. 7. Acad. Nauk. SSSR, Moscow: 221-238. [Russ.]

SARYTCHEVA, T. G., SOKOLSKAYA, A. N. 1952: A description of the Paleozoic Brachiopoda of the Moscow Basin. Trudy Paleont Inst. 38 (3): 3-303, 71pl. [Russ.]

SARYTCHEVA, T. G., WATERHOUSE, J. B. 1972: Some brachiopods of the family Retariidae from the Permian of northern Canada. Paleont. Zhurn. 6 (4): 501-513, pl. 7, 8. [Russ.]

SAVAGE, N. M. 1996: Classification of Paleozoic rhynchonellid brachiopods. *In* P. Copper & J. Jin (ed.) Brachiopods: 249-260. A. A. Balkema, Rotterdam.

_____ 2002a: Family Petasmariidae Savage, 1996. *In* R. L. Kaesler (ed.) Treatise on Invertebrate Paleontology, Part H, Brachiopoda revised, vol. 4, Rhynchonelliformea part: 1189-1194. Geol. Soc. Amer., Univ. Kansas: Boulder, Colorado & Lawrence, Kansas.

_____2002b: Rhynchoporoidea. *In* R. L. Kaesler (ed.) Treatise on Invertebrate Paleontology, Part H, Brachiopoda revised, vol. 4, Rhynchonelliformea part: 1232-1235. Geol. Soc. Amer., Univ. Kansas; Boulder, Colorado & Lawrence, Kansas.

SCHRADER, F. C. 1902: Geological section of the Rocky Mountains in northern Alaska. Geol. Soc. America Bull. 13: 233-253.

SCHUCHERT, C. 1913: Class 2. Brachiopoda. *In* ZITTEL, K. A. von Text-book of Paleontology, vol.

1 (1), 2nd ed., translated and edited by C. R. Eastman: 355-420, fig. 526-636. MacMillan & Co. Ltd, London.

SCHUCHERT, C., COOPER, G. A. 1931: Synopsis of the brachiopod genera of the suborders Orthoidea and Pentameroidea, with notes on the Telotremata. Amer. J. Sci. (ser. 5) 22: 241-255.

_____ , _____ 1932: Brachiopod genera of the suborders Orthoidea and Pentameroidea. Peabody Museum of Nat. Hist. Mem. 4 (1): 1-270, A + 29pl.

SELLERS, D. H. A., FURNISH, W. M. 1960: Mississippian ammonoids from northwestern Canada. J. Paleont. 34: 1124-1128.

SEMICHATOVA, S. V. 1941: Bashkirian brachiopods of the Soviet Union. 1. Genus *Choristites* Fischer. Trudy Paleont. Inst. 12 (4). [Russ.]

_____ 1969: Brachiopods from the Bashkirian Stage of Mt Bashkiria. Fauna and Paleozoic stratigraphy of the Russian Platform. Trudy VNIGRI 93: 163-173, 3pl. [Russ.]

_____ 1975: *In* GARANJ, I. M., GUSEVA, S. N., DEVINGTAL, V. V., DONAKOVA, L. M., ENOKYAN, N. V., KALASHNIKOV, N. V., LAPINA, N. N., MIKHAYLOVA, E. N., NALIVKIN, D. V., SEMICHATOVA, S. V., STEPANOV, D. L., STEPANOVA, G. A., SHESTAKOVA, M. F., EINOR, O. L. Brakhiopody. *In* D. L. Stepanov, A. K. Krylova, L. P. Grozdilova, V. M. Pozner, & A. A. Sultanaev (ed.) Paleont. Atlas Kamennougolnykh Otloz. Urala, Nedra, Leningrad: 154-248. [Russ.]

SHI, G. R. 1998: *Nahoniella*, a new name for *Yukonella* Shi & Waterhouse, 1996 (Spiriferida, Brachiopoda). J. Paleont. 72: 935.

SHI, G. R., WATERHOUSE, J. B. 1996: Lower Permian brachiopods and molluscs from the upper Jungle Creek Formation, northern Yukon Territory. Geol. Surv. Canada Bull. 424.

SHIMER, H. W., SHROCK, R. R. 1944: Index Fossils of North America. Massachusetts Inst. Technology: 837pp., 303pl. John Wiley & Sons, New York.

SHROCK, R. R., TWENHOFEL, W. H. 1953: Principles of Invertebrate Paleontology, 2nd edit. McGraw-Hill, New York, Toronto & London: xx + 816pp.

SHUMARD, B. F. 1855: Description of a geological section on the Mississippi River, from St Louis to Commerce. Geol. Surv. Missouri, Ann. Rep. 1-2 (2): 137-208.

SIMANAUSKAS, T. 1996: Una nueva especie de *Lanipustula* (Productoidea, Brachiopoda) from Patagonia, Argentina. Alcheringa 26: 465-474.

SLUSAREVA, A. D. 1958: On the Kazanian spirifers. Trudy Paleont. Inst. 118 (3): 581-583. [Russ.]

SOWERBY, J. 1812-1815: The Mineral Conchology of Great Britain 1: iv + 1-234, 102pl. J. Sowerby, London.

____ 1821-1822: The Mineral Conchology of Great Britain 4: 1-113. J. Sowerby, London.

STAINBROOK, M. A. 1943: Strophomenacea of the Cedar Valley Limestone of Iowa. J. Paleont. 17: 39-59, pl. 6, 7.

STEHLI, F. G. 1954: Lower Leonardian brachiopods of the Sierra Diablo. Bull. Amer. Mus. Nat. Hist. 105: 257-358.

STEPANOV, D. L. 1934: The Brachiopoda of the bryozoan limestones of the Kolwa River region (northern Ural). Pt 1. Strophomenacea. Oil-Geol. Inst. Trudy A 37: 1-63. [Russ.]

_____ 1948: The Upper Carboniferous Brachiopoda of Bashkiria. Trudy VNIGRI (n. s.) 22: 1-64, 12pl. [Russ.]

STEPANOV, D. L., KRILOVA, A. K., GROZDILOVA, L. P., POZNER, V. M., SULTANAEV, A. A. (ed.) 1975: Paleontological Atlas for Carboniferous beds of the Urals. Trudy VNIGRI: 1-359, 100pl. [Russ.]

STEVENS, C. H. 1962: Stratigraphic significance of Pennsylvanian brachiopods in the McCoy area, Colorado. J. Paleont. 36: 617-629, pl. 91-95.

STUCKENBERG, A. 1898: Allgemeine geologische Karte von Russland. Blatt 127. Com. Géol. Mém. 16 (2): 1-362.

STURGEON, M. T., HOARE, R. D. 1968: Pennsylvanian brachiopods of Ohio. Ohio Geol. Surv. Bull. 63: 1-116.

SUTHERLAND, P. K., HARLOW, F. H. 1967: Late Pennsylvanian brachiopods from north-central New Mexico. J. Paleont. 41: 1065-1089.

_____ , _____ 1973: Pennsylvanian brachiopods and biostratigraphy in southern Sangre de Cristo Mountains, New Mexico. Mem. New Mexico Inst. Mining & Technology, State Bureau Mines & Mineral Res. 27.

SUTHERLAND, P. K., MANGER, W. L. 1979: Mississippian-Pennsylvanian shelf-to-basin transition Ozark and Ouachita regions, Oklahoma and Arkansas. Oklahoma Geol. Surv. Guidebook 19: 81p.

SUTTON, A. H. 1938: Taxonomy of Mississippian Productidae. J. Paleont. 12: 537-569.

SUTTON, A. H., WAGNER, O. E. Jnr 1931: New species of Chester fossils. J. Paleont. 5: 23-33, pl. 5.

SWAN, D. H. 1963: Classification of Genevievian and Chesterian (Late Mississippian) rocks of Illinois. Illinois State Geol. Surv. Rept of Investigations 216: 1-91.

TABOADA, C. 2010: Mississippian-Early Permian brachiopods from western Argentina: tools from middle- to high-latitude correlation, biogeographic and paleoclimatic reconstruction. Paleogeog. Palaeoclim. Palaeoecol. 298 (2010): 152-173.

TABOADA, A., SHI, G. R. 2011: Taxonomic review and evolutionary trends of Levipustulini and Absenticostini (Brachiopoda) from Argentina: Palaeobiogeographic and palaeoclimatic implications. Mem. Assoc. Aust'asian Palaeont. 41: 87-114.

THOMAS, G. A. 1971: Carboniferous and Early Permian Brachiopods from Western and Northern Australia. Bull. Bureau Mineral Res. Geol. Geophys. 56: 1-277, 31pl.

THOMAS, I. 1914: The British Carboniferous Producti, part 1: genera *Pustula* and *Overtonia*. Great Brit. Geol. Surv. Mem. 1 (4): 197-366, pl. 17-20.

TOLMATCHOFF, I. P. 1924: Fauna du Calcaire Carbonifère du Bassin Houiller de Kousnetz. Mat. Obsh. Priklad. Geol. 25: 1-320, pl. 1-5, 8-11, 18-20. [Russ.]

TRAUTSCHOLD, H. 1876: Die Kalkbrueche von Mjatschkowa. Forzet. Nouv. Mém. Soc. Impériale Naturalist. Moscou 13 (5): 325-374.

TSCHERNYSCHEW, F. N. 1902: Die Obercarbonischen Brachiopoden des Ural und des Timan. Com. Mém. Géol. 16 (2). [Russ., German].

USTRITSKY, V. I. 1960: Carboniferous and Permian Stratigraphy and Fauna of western Kunmon (Kunlunshan) Mountains. Mem. Geol. Inst. Geol. Min. P. R. China 5 (1): 1-132, 25pl.

_____ 1962: New data on Permian brachiopods from Spitsbergen. Sbornik Statei Paleont. Biostrat. 28: 74-89, 3pl. [Russ.]

USTRITSKY, V. I., CHERNYAK, G. E. 1963: Biostratigraphy and brachiopods of the Upper Paleozoic of Taimyr. Trudy Nauchno-Issled. Inst. Geol. Arkt. (NIIGA) 34: 1-139. [Russ.]

VERNEUIL, E. de 1845: Paléontologie. Mollusques. Brachiopodes. *In* MURCHISON, R. I., VERNEUIL, E. de, KEYSERLING, A. Géologie de la Russie d'Europe et des Montaignes de l'Oural. Vol. 2 (3): 37-294, pl. 11, 15-18. John Murray, London & Bertrand, Paris.

VOLGIN, V. I. 1960: Brachiopods of the Upper Carboniferous and Lower Permian deposits of southern Fergana. Leningr. Ord. Lenina. Gosud. Univ. Zhadanova. Izdatel. Leningrad Univ.: 1-203, pl. 1-18. [Russ.]

VOLGIN, V. I., KUSHNAR, L. V. 1975: Lower Visean brachiopods and bivalve molluscs from southern Fergana. L. Izdatel.-vo Leningrad: 1-112, 10pl.

WAAGEN, W. 1883: Salt Range Fossils 1. Productus Limestone Fossils, Brachiopoda. Palaeont. Indica (ser. 13) 4 (2): 391-546, pl. 29-49.

_____ 1884: Salt Range Fossils, vol 1, part 4. Brachiopoda. Palaeont. Indica (ser. 13) 4 (3): 547-728, pl. 50-81.

_____ 1885: Salt Range Fossils, vol 1, part 4. Brachiopoda. Palaeont. Indica (ser. 13) 4 (5): 729-770, pl. 82-86.

WAGNER, R. H., WINKLER PRINS, C. F. 1991: Major subdivisions of the Carboniferous System. X1 Congr. Internat. Strat. Geol. Carbonifère, Beijing, Compte Rendu 1 (1991): 213-245.

WALCOTT, C. D. 1884: Paleontology of the Eureka district. U. S. Geol. Surv. Mon. 8: 1-298, 24pl.

WANG YU 1955: Brachiopoda. *In* The Index fossils of China 2. Nanjing Inst. Geol. Paleont. Acad. Sinica (ed.): 465-470. Science Press, Beijing. [Chin.]

WANG YU, JIN YUGAN, FANG DA-WEI 1964: Brachiopods from China: 59-136, pl. 59-136. Science Press, Beijing. [Chin.]

WATERHOUSE, J. B. 1959: Genus *Leptalosia* Dunbar & Condra. N. Z. J. Geol. Geophys. 2: 338-341.

_____ 1964: Permian brachiopods of New Zealand. N. Z. Geol. Surv. Paleont. Bull. 35: 1-287.

_____ 1965: The Permian spiriferoid genus *Ambikella* Sahni & Srivastava (1956) and its relationship to *Ingelarella* Campbell (1959) and *Martiniopsis* Waagen (1883). Trans. Roy. Soc. N. Z. Geol. 5 (12): 159-170.

_____ 1966: Lower Carboniferous and Upper Permian brachiopods from Nepal. Geol. Bundesanst. Jb. 12: 5-99, 16pl.

_____ 1967: Proposal of series and stages for the Permian in New Zealand. Trans. Roy. Soc. N. Z. Earth Sci. 5: 161-180.

_____ 1968a: New species of *Megousia* Muir-Wood & Cooper and allied new genus from the Permian of Australia and North America. J. Paleont. 42: 1171-1185, 3pl.

_____ 1968b: The classification and descriptions of Permian Spiriferida (Brachiopoda) from New Zealand. Palaeontographica A 129: 1-94.

_____ 1968c: Report on fossils from the northern Yukon Territory and northern British Columbia,

prepared by J. B. Waterhouse, University of Toronto, for E. W. Bamber, 1968. NTS 116F, G, I, J, P, 94K. Geological Survey of Canada, Paleontological Report C3-1968-JBW: 72pp. Unpublished, available at Geological Survey of Canada, Calgary.

_____ 1968d: Report on fossils from the northern Yukon Territory, prepared by J. B. Waterhouse, University of Toronto, for E. W. Bamber, 1968. NTS 116H. Geological Survey of Canada, Paleontological Report C4-1968-JBW: 16pp. Unpublished, available at Geological Survey of Canada, Calgary.

_____ 1971: See BAMBER, E. W., WATERHOUSE, J. B.

_____ 1975: New Permian and Triassic brachiopod taxa. Pap. Dep. Geol. Univ. Qld 7 (1): 1-23.

_____ 1978: Permian Brachiopoda and Mollusca from northwest Nepal. Palaeontographica A 160 (1-6): 1-175.

_____ 1981: Age of the Rat Buri Limestone of southern Thailand. *In* The Permian stratigraphy and palaeontology of southern Thailand. Geol. Surv. Mem. 4: 1-42. Bangkok, Thailand.

_____ 1982: New Carboniferous brachiopod genera from Huai Bun Nak, northeast Thailand. Paläont. Zeit. 56 (1/2): 39-52, Fig. 1-5.

_____ 1986: Late Palaeozoic Scyphozoa and Brachiopoda (Inarticulata, Strophomenida, Productida and Rhynchonellida) from the southeast Bowen Basin, Australia. Palaeontographica A 193 (1-4): 1-76.

_____ 1987: Late Palaeozoic Mollusca and correlations from the south-east Bowen Basin, east Australia. Palaeontographica A 198 (4-6): 129-233, 14pl.

_____ 1998: Ingelarelloidea (Spiriferida: Brachiopoda) from Australia and New Zealand, and reclassification of Ingelarellidae and Notospiriferidae. Earthwise 1: 1-46.

_____ 2001: Late Paleozoic Brachiopoda and Mollusca, chiefly from Wairaki Downs, New Zealand, with notes on Scyphozoa and Triassic ammonoids and new classifications of Linoproductoidea (Brachiopoda) and Pectinida (Bivalvia). Earthwise 3: 1-195.

_____ 2002a: The stratigraphic succession and structure of Wairaki Downs, New Zealand, and its implications for Permian biostratigraphy of New Zealand and marine Permian of eastern Australia and Gondwana. Earthwise 4: 1-260.

_____ 2002b: Classification within Productidina and Strophalosiidina (Brachiopoda). Earthwise 5: 1-60.

_____ 2004: Some new subfamilies, genera and species of Suborder Productidina (Brachiopoda). Earthwise 7: 1-46.

_____ 2010: New taxa of Late Paleozoic Brachiopoda and Mollusca. Earthwise 9: 1-134.

_____ 2013: The evolution and classification of Productida (Brachiopoda). Earthwise 10: 1-535.

_____ 2015: Early Permian Conulariida, Brachiopoda and Mollusca from Homevale, central Queensland. Earthwise 11: 1-390.

_____ 2016: On the evolution and classification of Spiriferida (Brachiopoda). Earthwise 14: 1-434.

_____ 2018: Late Carboniferous and Early Permian Brachiopoda and Mollusca from the lower Jungle Creek and upper Ettrain Formations of the Yukon Territory, Canada. Earthwise 15: 1- 514.

WATERHOUSE, J. B., CHEN, Z.-Q. 2007: Brachiopoda from the Late Permian Senja Formation, Manang area, Nepal Himalaya. Palaeontographica A 280 (1-3): 1-69.

WATERHOUSE, J. B., GUPTA, V. J. 1977: Brachiopods from the Carboniferous Fenestella Shales of Kashmir. Rec. Researches in Geol. 3: 145-187, 6pl.

_____ , _____ 1979: Early Carboniferous brachiopods from the Syringothyris Limestone and Fenestella shales of Kashmir. Contrib. Himal. Geol. 1: 108-146, 16pl.

WATERHOUSE, J. B., PIYASIN, S. 1970: Mid-Permian brachiopods from Khao Phrik, Thailand. Palaeontographica A 135 (3-6): 83-197.

WATERHOUSE, J. B., WADDINGTON, J. 1982: Systematic descriptions, paleoecology and correlations of the Late Paleozoic subfamily Spiriferellinae (Brachiopoda) from the Yukon Territory and the Canadian Arctic Archipelago. Bull. Geol. Surv. Canada 289: 1-79, 8pl.

WATERLOT, G. 1932: Les Productus du terrain houiller du nord de la France. Ann. Soc. Nord 57: 145-176.

WELLER, S. 1909: Kinderhook faunal studies. V. The fauna of the Fern Glen Formation. Geol. Soc. Amer. Bull 20: 265-332, pl. 10-15.

_____ 1910: Internal characters of some Mississippian rhynchonelliform shells. Geol. Soc. America Bull. 21: 497-516.

_____ 1914: The Mississippian Brachiopoda of the Mississippi Valley Basin. Illinois State Geol. Survey. Monograph 1: 508pp., 83pl.

WHITE, C. A. 1865: Description of new species of fossils from the Devonian and Carboniferous rocks of the Mississippi Valley. Boston Soc. Natural History Proc. (1862) 9: 8-33, 5 fig.

WHITFIELD, R. P. 1908: Notes and observations on Carboniferous fossils and semifossil shells, brought home by members of the Peary expedition of 1905-1906. Amer. Mus. Nat. Hist. Bull. 24: 51-58, 4pl.

WILLIAMS, A. 1953: The classification of the strophomenoid brachiopods. Washington Acad. Sci. J. 43: 1-13.

_____ 1956: The calcareous shell of the Brachiopoda and its importance to their classification. Biological Reviews 31: 243-287.

_____ 1965: Order Strophomenida Öpik, 1934. R. C. Moore (ed.) Treatise on Invertebrate Paleontology. Part H Brachiopoda. Vol. 1:361-412. Geol. Soc. Amer., University of Kansas, New York & Lawrence.

WILLIAMS, A., BRUNTON, C. H. C. 1993: Role of shell structure in the classification of the orthotetidine brachiopods. Palaeontology 36: 931-966.

_____ , _____ 2000: Orthotetidina. *In* R. L. Kaesler (ed.) Treatise on Invertebrate Paleontology, Part H, Brachiopoda revised, vol. 3, Linguliformea, Craniiformea, and Rhynchonelliformea part: 644-681. Geol. Soc. Amer., Univ. Kansas; Boulder, Colorado & Lawrence, Kansas.

WILLIAMS, A., CARLSON, S. J., BRUNTON, C. H. C., HOLMER, L. E., POPOV, L. E. 1996: A Supra-ordinal Classification of the Brachiopoda. Philosoph. Trans. Roy. Soc. London (ser. B) 351: 1171-1193.

WINKLER PRINS, C. F. 1968: Carboniferous Productidina and Chonetidina of the Cantabrian Mountains (NW Spain): systematics, stratigraphy and palaeoecology. Leidse Geol. Medelingen 43: 41-126, pl. 1-9, tables 1-3.

_____ 1982: Brachiopods and the Lower/Middle Carboniferous (Mississippian/Pennsylvanian) boundary. Subcommission on Carboniferous Stratigraphy IUGS Publ. 11: 61-68.

WRIGHT, A. D. 1965: Superfamily Enteletacea. *In* R. C. Moore (ed.) Treatise on Invertebrate Paleontology Part H. Brachiopoda: 328-346. Geol. Soc. Amer., Univ. Kansas Press, New York & Lawrence.

ZAVODOWSKY, V. M. 1970: *In* ZAVODOWSKY, V. M. & STEPANOV, D. L. Brachiopoda. Field Atlas of the Permian fauna and flora of the northeast USSR. Pt 2. Severo-Vostoch. Ordena Trydovogo Krasnogo Znam. Geol. Uprav. Magadan: 70-182, 96pl. [Russ.]

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Page numbers in bold refer to systematic descriptions for species