

Ostracods as palaeoenvironmental indicators in the Lower Carboniferous Yoredale Series of northern England

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ABSTRACT—The ostracod fauna and vertical changes in its composition were examined in a shale sequence of the 5-Yard Limestone cyclothem (Yoredale Series) at a locality in Bishopdale, N. Yorkshire. The ostracod taxa are mainly confined to three superfamilies: Kirkbyacea, Healdiacea and Bairdiacea. The co-occurrence of several relatively short-ranging species such as *Kirkbya quadrata*, *Cribroconcha insculpta* and *Bairdiolites elevatus* suggests a Late Brigantian age. Four new species are described: *Cornigella posteroextensa*, ? *Eriella minima*, *Rectobairdia bavarica* and *Roundyella binoda*.

Fluctuations in influx of terrigenous mud and water turbulence, related to delta growth, appear to have been the main environmental parameters that controlled the ostracod distribution and abundance along a nearshore-offshore gradient. Three different ostracod assemblages are recognized. A *Roundyella-Cribroconcha* assemblage, dominated by kirkbyacean and healdiacean ostracods, represents a quiet, nearshore environment with a fairly high depositional rate of terrigenous mud. A *Bairdia* assemblage, higher in the section, is dominated by bairdiacean ostracods that lived in a more turbulent, relatively offshore environment with less input of terrigenous sediment. A third, intermediate assemblage consists of almost equal amounts of bairdiacean and kirkbyacean ostracods, and reflects a transition from the *Bairdia* to the *Roundyella-Cribroconcha* assemblage.

INTRODUCTION: PALAEOGEOGRAPHY AND SEDIMENTATION

The 5-Yard Limestone cyclothem is one of the cyclothem of the Yoredale Series of Great Britain that was deposited during the Brigantian stage in late Lower Carboniferous times (Moore, 1958), not far south of the Carboniferous equator (fig. 1). As described in an earlier paper (Masurel, 1987), Great Britain then was an area of high relief with uplifted mountain chains in Scotland adjacent to major interior basins, and block and basement tectonics in northern England, subsequently inundated by marine sedimentation spreading across the British continental shelf from south to north. The basal bioclastic limestones and overlying shales and sandstones of the Yoredale succession reflect the passage from clear, limestone-forming seas to terrigenous delta progradation from the north.

METHODS OF STUDY

One of the sections of the 5-Yard Limestone cyclothem described by the author in 1987 (section 5; p. 231–236, figs. 1, 5c, 7, 8, table ID), was selected for the purpose of this study. It is located in Bishopdale, N. Yorkshire (fig. 1, 2).

Samples were collected from horizons throughout the section. The purpose was to investigate the palaeo-environmental conditions that have been involved with vertical changes of lithology and fossil content in the stratigraphical column. Therefore, sampling horizons were widely spaced in relatively monotonous parts of the column, but closer where changes in lithology are distinct, e.g. the shale hori-

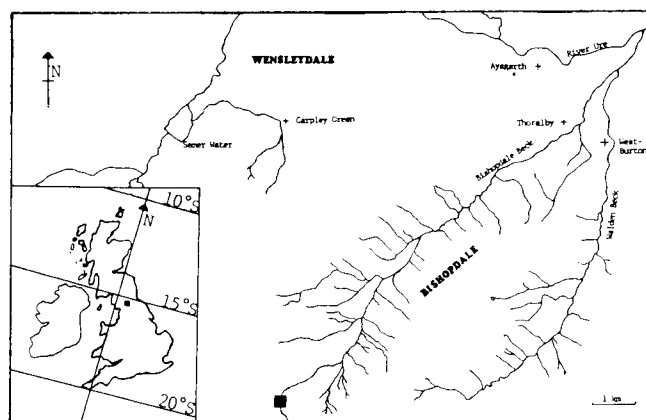


Fig. 1 Location of the section (marked by black square), N. Yorkshire, Great Britain; generalised palaeolatitude in the Early Carboniferous, based on palaeomagnetic data (McElhinny, 1973).

zons below, in and above the nodule beds and the *Gigantoproductus* zone (fig. 3, 4).

Sample material was oven-dried, weighed, and then immersed in petroleum. After about 2 hours the petroleum was replaced by boiling water, and the disaggregated material was wet-sieved and separated into different fractions.

PALAEOECOLOGY

The largest part of the sequence is characterised by a scarcity of ostracods. It is doubtful if the ostracods, which are often

disarticulated, are autochthonous. Ostracods and other bioclasts often show some degree of pyritisation, which indicates that deposition of mud took place under quiet, reducing conditions. Poor oxygenation of the water and a fairly high influx and depositional rate of clay may have been important limiting factors preventing most organisms from colonising the sea floor. Shales that exhibit a relatively high abundance and diversity of ostracods and other bioclasts are largely confined to horizons below the 75 cm sample, in and around the three main nodule beds, and above the third nodule bed (fig. 3, 4). These probably reflect periods of decreased sedimentation rate linked with a temporarily increased water turbulence. Most of the ostracods that occur here do not show signs of post-mortem transport, and probably formed part of autochthonous populations. Their shells are usually articulated and various growth stages are found. Several specimens of spinose forms such as *Cornigella tuberculospinosa* and *Cribroconcha insculpta* have been found with their spines still intact. The associated, stenohaline macrofauna which occurs at most of these fossiliferous shale horizons is dominated by benthic suspension feeders, most of which are probably indigenous. This, together with local concentrations of fossil debris, implies deposition in shallow, well-oxygenated water of normal marine salinity (Masurel, 1987).

The nodules that occur at 3 distinct, relatively fossiliferous shale horizons have been described by the present author (Masurel, 1987) and are interpreted as being algal in origin, since laminated structures were occasionally found in their Fe-rich matrix (dolomicrosparite). Furthermore, the matrix shows minor bioturbation phenomena and vague relicts of brachiopods, bryozoa, foraminifera and ostracods in cracks subsequently filled by calcite. The formation and diagenetic history of these nodules is probably analogous to that of septarian concretions, which are not uncommon in clayey sediments (Vandenbergh & Laga, 1986; Astin & Scotman, 1988). The nodule beds represent carbonate-rich sedimentation horizons, resulting from periods of reduced clay sedimentation. During these periods conditions apparently were suitable for growth of algae, which may have formed algal mats that were suitable for attachment by suspension feeders such as brachiopods and bryozoa. Nodules were formed as result of remobilisation and redistribution of carbonate at an early diagenetic stage, the final shape being determined by the original thickness of the carbonate-rich sedimentation horizon and the amount of carbonate available in the horizon (Vandenbergh & Laga, 1986).

ASSEMBLAGES

1. *Roundyella binoda* n. sp. - *Cribroconcha caneyensis* Assemblage

This assemblage occurs in dark grey, finely laminated, organic-rich mud-shales at 25 cm, 190-200 cm, 500-560 cm and 1075 cm and less distinctly at other horizons. The assemblage can be divided into 3 subassemblages, based

upon the relative occurrence of its two end members (see figs. 3, 4):

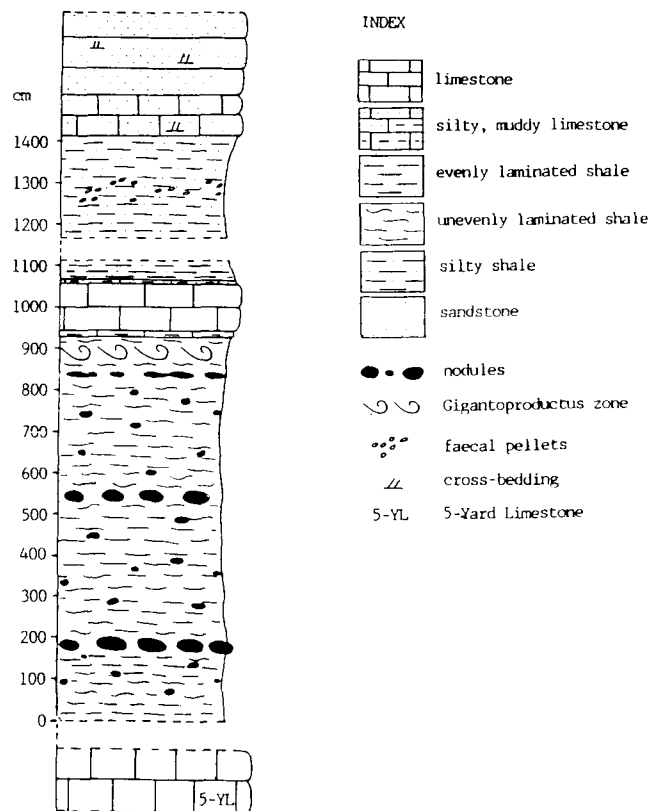


Fig. 2 Stratigraphic column of the studied section. For sampling positions see fig. 3.

A. *Roundyella binoda* dominates the ostracod fauna (400, 1075 cm), and is associated with only a scarcity of other taxa including *Cribroconcha caneyensis*.

B. *Roundyella binoda* and *Cribroconcha caneyensis* together dominate the ostracod fauna, which exhibits a variable diversity of other species (500-550 cm).

C. *Cribroconcha caneyensis* dominates, and is associated with a relatively high abundance and diversity of other species (560 cm).

Sub-assemblages B and C sometimes include significant numbers of the following ostracod taxa: *Scrobicula scrobiculata*, *Amphissites urei*, *Kirkbya quadrata*, *Healdianella* cf. *darwinuloides* and *Cribroconcha insculpta*. Accessory components in these sub-assemblages are *Bairdiolites elevatus*, *Cornigella tuberculospinosa*, *Hollinella radiata*, *Tetrasacculus mirabilis*, *Moorites elongatus*, and several others (fig. 4). It is noted that a relatively low diversity characterises sub-assemblage B in a sample from 500 cm, *Scrobicula scrobiculata* being the only important component that co-occurs with the two end members. The occurrence of the two kirkbyaceans *Amphissites urei* and *Kirkbya quadrata* is largely confined to fossiliferous shales between 540 and 560 cm (fig. 3). The diversity of microfauna as well

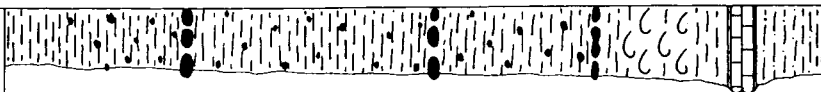
LITHOLOGY (not to scale; index see fig.2)																						
STRATIGRAPHIC HORIZONS (cm)	5	25	75	125	190	200	300	400	500	540	550	560	600	750	845	870	895	920	1075	1150		
OSTRACOD ASSEMBLAGES	1	1B	1	1	1B	1B	1	1A	1B	1B	1B	1C	1C	2	2	2	2	3	1A	3		
(FAIRLY) COMMON OSTRACOD TAXA																						
Roundyella binoda n. sp.	2	51		3	37	17	2	21	32	36	32	3						2	14			
Scrobicula scrobiculata (J., K. & B., 1884)	1	3	5		3	3	1		25	24	33	24	2				1					
Kirkbya quadrata Robinson, 1959		1			3					15	13	12										
Amphissites urei		2			1					28	14	38										
Healdianella cf. darwinuloides Posner, 1951	3	15	3	1	15	16		3		6	13	4							?	2		
Criboconcha insculpta Robinson, 1959	1	7				4				20	8	16										
C. caneyensis (Harlton, 1957)	2	28	1		6	9	2		47	48	66	38	2	1				7	1	1		
C. perplexa Robinson, 1959														1	1	?	?	12	14			
Bairdiocypris fomikhaensis Bushmina, 1968														?		7	9	6	?			
Bairdiolites elevatus Robinson, 1959		7									1			1	1	3						
Bairdia (incl. Rectobairdia) spp.						?			?	1					33	16	10	5	3	2		
Bairdiacypris subelongata (J. & K., 1879)															8	12	9	3				
ASSOCIATED MICROFOSSILS																						
Conodonts	+	+							+	+	+							+				
Crinoid ossicles	+	+	+						+	c	c	f	+						+	+		
Echinoid fragments	f	f	+						+	+	+	f	+			+	+	+	+	+		
Foraminiferids (Endothyrids)					+	+			+	+	+				f	c	c	+	f	f		
(Others)	f	f	+	+	+	+			+	c	f	f			+	+			+	+		
Gastropods	f	f	+	+	f	f	+		+	c	f	f	+	+	+	+			+	+		
Gigantoproductus juveniles ?	+	+							+		+	+	+	+	c	c	c	f	+			
Holothurian sklerodermites	+	+	+				+	+	+	+	+	f	f	+	+	+	+	+	+			
Plant leaflets	+	+	+						+	+	+	+							+			

Fig. 3 Distribution chart of ostracode taxa and associated microfossils. The number of specimens was counted in 50 gram-samples; +, f and c respectively represent a sporadic (1-5), fairly common (5-20) and common occurrence (20 or more), and ? a questionable assignment.

as macrofauna (Masurel, 1987: table 1D) shows a relatively high peak at these horizons. *Amphissites* and *Kirkbya* probably needed well oxygenated water for growth of their fairly large and elaborate carapaces.

Where the assemblage reappears at 1075 cm, just above the thin limestone, it is characterised by a low density and diversity (figs. 3, 4). A new, relatively common component is *Cribroconcha perplexa*, which was already fairly common in a transitional assemblage detected somewhat lower in the section (920 cm, see below).

2. *Bairdia* assemblage

This assemblage occurs in coarsely laminated, calcareous shales in and above the highest nodule bed, between 845 and 920 cm (fig. 2).

Bairdia is the most characteristic genus of the assemblage, associated with other bairdiaceans including *Rectobairdia* spp., *Bairdiocypris* spp., and, less commonly, *Bairdiolites elevatus*. Poor preservation of most of the ostracods in the calcareous shales made identification of species very dif-

ficult, but it is eliminated that there are probably more than 10.

Bairdiaceans are by far the most abundant ostracods in samples derived from 845 cm. The only accessory component of the assemblage is *Cribroconcha perplexa*, which is not found at lower horizons. The abundance of *Gigantoproductus* shows a peak slightly higher in the sequence, between 870 and 898 cm. *Gigantoproductus* was probably an opportunist that took advantage of a reduced mud sedimentation rate, an increased water turbulence supplying sufficient food and oxygen, and a lack of competition by other large benthic suspension feeders (Masurel, 1987, p. 232-233, fig. 8).

It appears that the bairdiacean ostracods had already become established before the explosive colonisation by this large brachiopod.

Bairdiocypris joins the assemblage at 870 cm, and remains a fairly common component.

Assemblages dominated by bairdiacean ostracods are indicative of offshore marine environments. Late Palaeo-

zoic faunas in which bairdiacean ostracods predominate have been described by many authors, e.g. Brondos & Kaesler (1976), Haack & Kaesler (1980), Bless (1983), Kaesler (1983), Crasquin (1984) and Devery (1987). Kornicker (1961) described ostracod associations from recent stable offshore sediments which were also dominated by bairdiaceans. This author concluded that an abundance of *Bairdia* specimens in ancient sediments may indicate deposition in shallow, warm (above 10°C) water of normal marine salinity (30-40 parts per thousand).

The fact that bairdiaceans do not reach significant numbers in the lower part of the sequence would suggest that conditions remained hostile to them. Only *Bairdiolites elevatus* appears to have been a fairly adaptable species, an inference drawn from its fairly common occurrence (in different growth stages) in a sample from 25 cm (fig. 3).

Accessory ostracods that were found in samples from 870 cm and 895 cm are *Coryellina reticosa* and the paraparchitaceans *Shishaella* cf. *williamsae* and *Shivaella armstrongiana*. The last two were typical inhabitants of shallow offshore environments (Bless, 1983).

3. Transitional assemblage

This assemblage occurs in coarsely laminated, calcareous shales above the *Gigantoproductus* zone (920 cm). It represents a transition from the *Bairdia* assemblage into the *Roundyella-Criboconcha* assemblage, indicating a gradual change of palaeo-environmental conditions.

Assemblage 3 consists of almost equal numbers of bairdiaceans (*Bairdia*, *Bairdiacypris*) and healdiaceans (*Criboconcha caneyensis*, *C. perplexa*), associated with only a few specimens of the kirkbyacean *Roundyella binoda*.

A common occurrence of healdiid ostracods is often assumed to be indicative of relatively nearshore, muddy conditions (e.g. Bless, 1983 and Melnyk, 1985). It is therefore suggested that the main reason for the change in the ostracod fauna and for the extinction of *Gigantoproductus* may have been a slight increase of mud influx and sedimentation rate, related to a slowly retreating shoreline. *Gigantoproductus*, which probably had taken advantage of a temporarily reduced sedimentation rate, appears to have become locally extinct very quickly (Masurel, 1987, fig. 8), even before the appearance of significant amounts of healdiaceans in the ostracod fauna. Opportunists are characterised by relatively unstable populations, and often become extinct quickly at the onset of unfavourable conditions (Levinton, 1970).

CONCLUSIONS AND DISCUSSION

Depositional environment

The main part of the shale sequence, characterised by a scarcity of ostracods, was deposited in quiet shallow water of the prodelta area. Poor oxygenation of the water and a high influx of terrigenous mud probably inhibited colonisation by ostracods and other benthic organisms. Nevertheless, fairly diverse ostracod assemblages, sometimes containing more than 15 species, have been recognised at several different

shale horizons. These are usually associated with a diversity of other microfossils (fig. 3), and an autochthonous macrofauna consisting mainly of suspension feeders, including stenohaline rugose corals (Masurel, 1987). The fossiliferous shale horizons thus reflect episodes of temporarily increased water circulation and reduced influx and deposition of mud under normal marine salinity conditions.

Assemblage 1 consists mainly of kirkbyacean and healdiacean ostracods (Fig. 3: 190, 550 cm). These must have had some tolerance to the influx of clay under very quiet conditions. The assemblage is dominated by either one or both of its end members, the ratio between which forms a basis for further division into 3 sub-assemblages (1A, 1B, 1C). *Roundyella binoda* was probably the most adaptable species, dominating a very impoverished ostracod fauna (sub-assemblage 1A at 400 cm, where other, often pyritised bioclasts only sporadically occur (Fig. 3, 4). At other shale horizons, where both end members or only *Criboconcha caneyensis* dominate (sub-assemblages 1B and 1C), a fairly high diversity of ostracod species is usually found.

The most important and consistent components of assemblage 1, besides its end members, are *Scrobicula scrobiculata*, *Amphissites urei*, *Kirkbyella quadrata*, *Healdianella* cf. *darwinuloides* and *Criboconcha insculpta*.

Assemblage 2 is dominated by bairdiacean ostracods (Fig. 3: 845 cm), occurring in calcareous shales. It probably occupied a more offshore, open marine environment that was less influenced by the delta. Micro- and macrofauna contain evidence of a considerably reduced sedimentation rate of mud in well oxygenated, nutrient-rich, shallow water.

Assemblage 3 is transitional between assemblages 1 and 2, consisting of almost equal numbers of bairdiacean and healdiacean ostracods, associated with considerably fewer kirkbyaceans (Fig. 3: 920 cm). This assemblage reflects depositional conditions which are intermediate between that of the relatively nearshore, clastic-dominated environment of the kirkbyaceans and healdiaceans (assemblage 1), and the more offshore, carbonate-dominated environment of the bairdiaceans (assemblage 2).

The ostracod assemblages and related palaeo-environmental conditions described above are comparable with those recognised by Devery (1987), in the Bangor Limestone Formation (Chesterian, Mississippian) of Alabama. He described ostracods from intercalations of argillaceous limestones and calcareous shales, which were probably deposited in a middle shelf-carbonate environment where delta progradation played an important role. Salinity percentages probably remained within normal marine levels. Devery related his assemblages to a nearshore-offshore gradient, and concluded that fluctuations in the influx of terrigenous sediment and small variations in salinity were probably the main environmental parameters that controlled the ostracod distribution along the nearshore-offshore coenocline.

The *Roundyella-Criboconcha* assemblage (1) is comparable with the *Kirkbyella gutkei* subassemblage recognised

STRATIGRAPHIC HORIZONS (cm)	5	25	75	125	190	200	300	400	500	540	550	560	600	750	845	870	895	920	1075	1150
OSTRACOD ASSEMBLAGES	1	1B	1	1	1B	1B	1	1A	1B	1B	1B	1C	1C	2	2	2	2	3	1A	3
<u>LESS COMMON OSTRACOD TAXA</u>																				
<i>Bairdia</i> (B.) <i>beedei</i> Ulrich & Bassler, 1906																1			1	1
B. (B.) <i>harltoni</i> Cooper, 1946																	1			
B. (<i>Rectobairdia</i>) <i>bavarica</i> n. sp.																		2		
<i>Bairdiacypris</i> cf. <i>curvis</i> (Cooper, 1941)												1								
B. sp. aff. <i>robusta</i> Kummerow, 1939									1											
<i>Cavellina</i> cf. <i>benniei</i> (J., K. & B., 1884)		1																		
<i>Cornigella</i> <i>posteroextensa</i> n. sp.										2										
C. <i>tuberculospinosa</i> (Jones & Kirkby, 1886)		2							1	1										
<i>Coronakirkbya</i> <i>cornuta</i> (Robinson, 1978)													2							
<i>Coryellina</i> cf. <i>reticosa</i> (Jones & Kirkby, 1886)																1				
<i>Cryptophyllus</i> sp. (<i>Eridostracan</i> ?)	1	4						1		1	1							?		
<i>Discoidella</i> sp.		2				1				2		?								
? <i>Eriella minima</i> n. sp.						2														
<i>Healdia</i> <i>cornigera</i> (Jones & Kirkby, 1879)																?		?		
<i>Hollinella</i> <i>radiata</i> (Jones & Kirkby, 1886)	1	2				1					1	1								
<i>Kegelites</i> sp.										1										
<i>Monoceratina</i> <i>antiqua</i> (Jones & Kirkby, 1886)											1									
<i>Moorites</i> <i>elongatus</i> (Jones & Kirkby, 1886)		1								2		2								
<i>Sargentina</i> sp.																			?	
<i>Shishaella</i> cf. <i>williamsae</i> Sohn, 1971																1		1		
<i>Shivaella</i> <i>armstrongiana</i> (Jones & Kirkby, 1886)																	1			
<i>Tetrasacculus</i> <i>mirabilis</i> (Croneis & Gale, 1938)		1								1	1	1								
<i>Youngiella</i> sp.												?								

Fig. 4 Distribution chart of ostracode taxa not listed in fig. 3. The number of specimens was counted in 50 gram samples.

in the *Sansabella* assemblage of Devery, which is characterised by a large number of healdiaceans and kirkbyaceans, and thought to have occupied a nearshore environment.

The *Bairdia* assemblage (2) can be compared with Devery's subgroup 1 of the *Bairdia golcondensis* assemblage, characterised by an abundance of bairdiaceans and common occurrence of kirkbyaceans, associated with endothyraean foraminifera, indicative of the offshore environment.

The Transitional assemblage (3) is comparable with subgroup 2 of the *Bairdia golcondensis* assemblage of Devery, which contains a glyptopleurid-bairdiacean fauna and represents a transitional phase between a nearshore and an offshore assemblage.

Biostratigraphy and palaeogeography

The ostracod fauna of the 5-Yard Limestone cyclothem contains several short range species that have been recorded from the Cawdor Limestones of the Derbyshire massif, England (Robinson, 1959), and are diagnostic for the upper Brigantian stage, e.g. *Criboconcha insculpta*, *C. perplexa*, *Kirkbya quadrata* and *Bairdiolites elevatus*. The stratigraphic range of two species that were known from the Pendleian to Arnsbergian of Great Britain (Robinson, 1978), *Coryellina reticosa* and *Bairdia beedei*, is here extended.

The fauna shows affinity to Lower Carboniferous ostra-

cod faunas from Belgium, Germany, France, Russia and North Africa, described by several authors, e.g. Bushmina (1968, 1970, 1975), Becker & Bless (1974), Becker et al. (1974), Bless & Massa (1982) and Crasquin (1984). Several forms that are conspecific or closely related to Russian species, e.g. *Shivaella armstrongiana*, *Bairdiocypris fomikhaensis* and *Bairdiocypris* sp. aff. *robusta*, appear to occur later in western Europe than in Russia. This phenomenon was already noted by Bless (1983), and can be explained by considering palaeogeographic and palaeo-oceanic reconstructions of the Hercynian Ocean and adjacent areas during Visian times (Ziegler et al., 1979 and Dewey, 1985). A westward equatorial ocean current fed by the Uralian Ocean would have flowed along the northern margin of the Hercynian Ocean, whereas a weaker counter equatorial current would have flowed along the southern edge. extensive development of epicontinental shelves in the northern Hercynian Ocean further would have facilitated migration of ostracod larvae (Dewey, 1985). Evidence for westward migration can also be derived from the distribution of other faunal groups, such as conodonts. Higgins (1981) noted that the range of the cosmopolitan conodont species *Paragnathodus commutatus* is not identical in Eurasia and the Midcontinent of North-America. In Europe it appears at the base of the Visian, but in the Midcontinent its first appearance is in

the late Visean.

The ostracod assemblages described in this paper are equivalent in age and partly conspecific to faunas from the Chesterian Kinkaid and Bangor Limestone formations of the Midcontinental United States (Cooper, 1942, 1947; Devery, 1987), and the upper units of the Codroy and Windsor Groups of Maritime Canada (Dewey, 1983, 1985 and Dewey & Fihraeus, 1987), all representing series of transgressive and regressive episodes. The chronostratigraphical relationship is based on several sources, e.g. Mamet (1970), Conil et al. (1976) and George et al. (1976). The Midcontinental faunas contain several forms that are conspecific to those described herein, such as *Criboconcha caneyensis*, *Cornigella tuberculospinosa* and *Tetrasacculus mirabilis*. The assemblages from Maritime Canada are often dominated by paraparchitacean ostracods, and show considerably less similarities to both the Midcontinental and the faunas described herein. This can be explained by a restricted circulation of sea water and prevailing hypersaline conditions in the Maritime Basin, which was a shallow embayment of the Hercynian Ocean. Dewey (1985) considered the low affinity between the Midcontinental and eastern Canadian ostracod faunas to be a function of the Appalachian barrier and circulation of ocean currents away from the Midcontinent in northward direction. Data obtained in this study on the other hand provide evidence of a faunal connection between northern England and the Midcontinent during the late Visean, thus implying a less isolated position of the latter.

SYSTEMATIC PALAEONTOLOGY

The material described in this paper is housed in the collections of the Rijksmuseum van Geologie en Mineralogie, Leiden, The Netherlands, under reference numbers RGM 350.501-350.638.

Synonymy lists are selective and refer only to important revisions and citations. Dimensions are in millimetres and the following abbreviations are employed: RV right valve and LV left valve; DM dorsal margin and VM ventral margin; L maximum length, H maximum height and W maximum width.

Class Ostracoda Latreille, 1806

Order Palaeocopida Henningsmoen, 1953

Suborder Beyrichicopina Scott, 1961

Superfamily Drepanellacea Ulrich & Bassler, 1923

Family Aechminellidae Sohn, 1961

Genus *Cornigella* Warthin, 1930

Cornigella tuberculospinosa (Jones & Kirkby, 1886)
(Pl. 6, figs. 2a, b)

Diagnosis. Carapace subovate-cuneiform in lateral view. DM straight, VM convex, ends rounded, anterior broader. Maximum height anterior of mid-length. Surface of each valve marked by a strong, slightly backward pointing dorsal spine (just posterior of mid-length) and six nodes.

1886 *Beyrichia tuberculospinosa* Jones & Kirkby, p. 258, Pl. 8, Figs. 7-8.

1947 *Cornigella tuberculospinosa* - Cooper, p. 89, Pl. 21, figs. 4-6

1951 *Cornigella tuberculospinosa* - Posner, p. 43, Pl. 15, fig. 5.

1987 *Cornigella tuberculospinosa* var. A - Devery, p. 82, Pl. 3, figs. 1-2.

Material. 4 carapaces, two of which are completely pyritised.

Description. The most prominent node is located in front of the dorsal spine, five others border the free margin at some distance, including a weakly developed node behind the dorsal spine. Surface regularly reticulated, spines and nodes almost smooth with scattered pits.

Remarks. *Cornigella tuberculospinosa* may show some variation in the number of nodes. The specimens described herein closely resemble those figured by Jones & Kirkby (1886) and Devery (1987).

Occurrence: Upper Visean of Great Britain, Upper Mississippian to Pennsylvanian of U.S.A., Lower Carboniferous of U.S.S.R.

Cornigella posteroextensa sp. nov.
(Pl. 6, figs. 1a,b)

? 1987 *Cornigella tuberculospinosa* var. B - Devery, p. 82, Pl. 3, fig. 10.

Derivation of name. Latin, referring to extended posterior extremity, compared with *C. tuberculospinosa* (Jones & Kirkby, 1886).

Diagnosis. Carapace subovate-cuneiform in lateral view. DM straight, VM convex, ends rounded, anterior broader. Maximum height anterior of mid-length. Surface of each valve marked by a slightly backward pointing dorsal spine (just posterior of mid-length) and 5 distinct nodes.

Holotype. RGM 350.505

Paratype. RGM 350.506

Explanation of Plate 1

Figs. 1-3 *Amphissites urei* (Jones, 1859)

Fig. 1 RGM 350.516, 560 cm, LV, L 0.74 mm, H 0.44 mm (x 100).

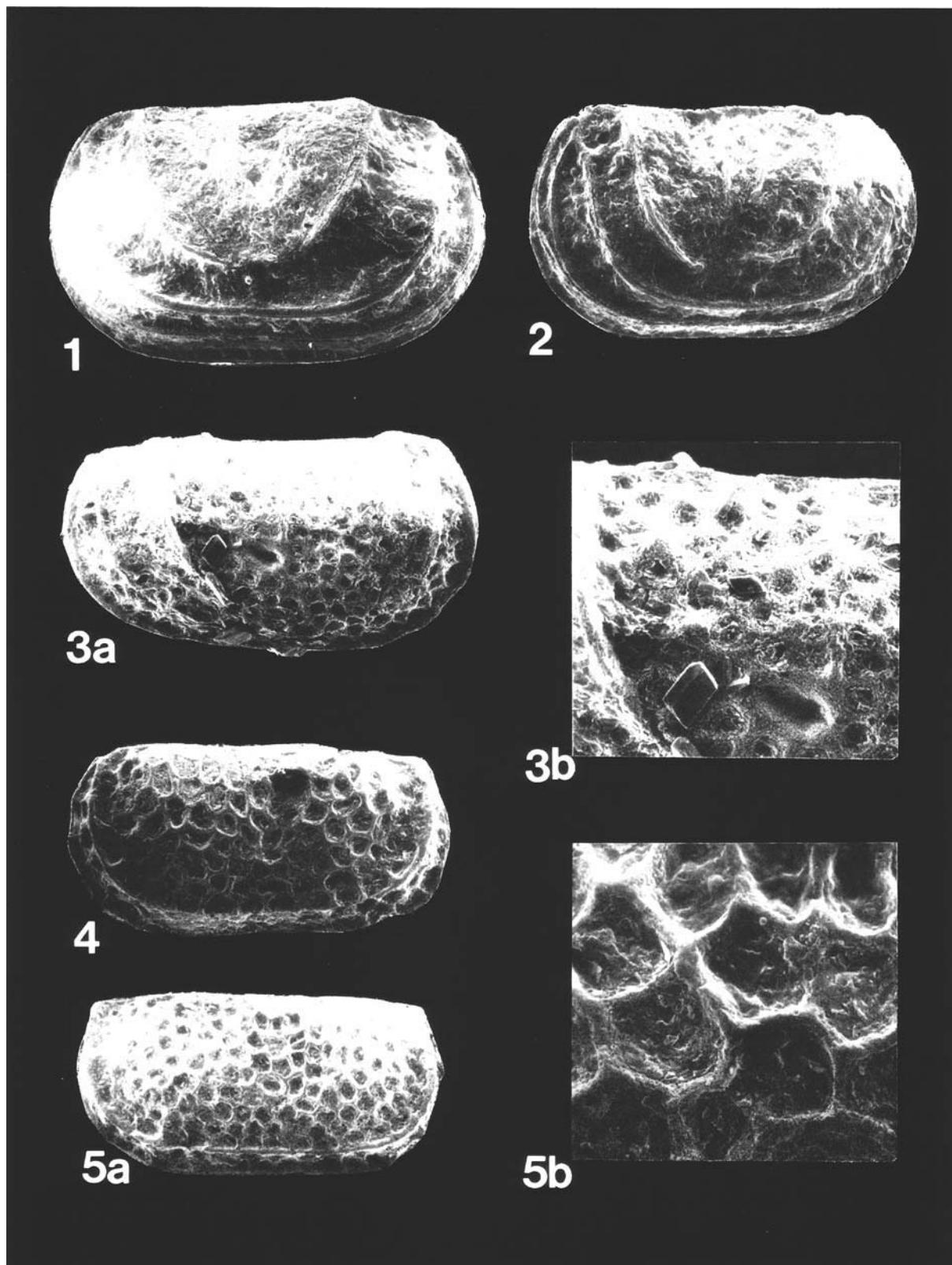
Fig. 2 RGM 350.517, 550 cm, LV, L 0.54 mm, H 0.32 mm (x120).

Fig. 3a-b RGM 350.518, 560 cm, L 0.44 mm, H 0.23 mm: fig. 3a, RV (x160); fig. 3b, detail of RV (x320)

Figs. 4-5 *Kirkbya quadrata* Robinson 1959.

Fig. 4 RGM 350.523, 560 cm RV, L 0.40 mm, H 0.21 mm (x160).

Fig. 5a-b. RGM 350.524, 540 cm, L 0.76 mm, H 0.38 mm: fig. 5a, RV (x80); fig. 5b, detail of RV (x400).



Material. Two complete carapaces.

Type locality. See Fig. 2. It corresponds to locality 55 of Moore (1958) and section 5 of Masurel (1987: fig. 1) in Bishopdale, northern England.

Description. The two specimens of this new species distinguish themselves from *C. tuberculospinosa* (Jones & Kirkby, 1886) by a more elongated shape, due to a slightly extended posterior end. The dorsal spines are less pronounced and the reticulation pattern is variable, reticulum being relatively smaller in the posterior part, along the margins and on the nodes. The slightly swollen anterior is separated from the flattened posterior half of the carapace by a more or less distinct, narrow sulcus in front of the dorsal spine.

Remarks. The new species shows similarities in shape, presence of a median sulcus, and delicacy of the dorsal spines with *C. tuberculospinosa* var. *B* from the Upper Mississippian Bangor Limestone formation of U.S.A., described by Devery (1987). It is distinguished from the latter by the variation in reticulation on different parts of the carapace. Furthermore it lacks the posterodorsal tubercle that marks the surface of all specimens of *C. tuberculospinosa* var. *B* (Dewey, personal communication), which, however, may be due to abrasion.

Superfamily Hollinacea Swartz, 1936

Family Hollinidae Swartz, 1936

Genus *Hollinella* Coryell, 1928

Hollinella (*Keslingella*) *radiata* (Jones & Kirkby, 1886)

(Pl. 7, fig. 5)

Synonymy list and diagnosis. See Bless & Jordan (1972, p. 54-56, Pl. 19, figs. 1-5, Pl. 20, figs. 1-7).

Material. 6 recognisable fragments of single valves.

Occurrence. Lower Carboniferous of Great Britain, Germany, U.S.S.R. and U.S.A. (Bless & Jordan, 1972).

Genus *Tetrasacculus* Stewart, 1936

Tetrasacculus mirabilis (Croneis & Gale, 1938)

(Pl. 6, figs. 3a-b, Pl. 7, fig. 1)

1938 *Pterocodella mirabilis* - Croneis & Gale, p. 264-265, fig. 5.

1941 *Tetrasacculus mirabilis* - Cooper, p. 16, Pl. 2, figs. 1-2.

1978 *Tetrasacculus mirabilis* - Robinson, p. 130, Pl. 1, fig. 4.

1987 *Tetrasacculus mirabilis* - Devery, p. 83-84, Pl. 1, figs. 1-3.

Diagnosis. Carapace subovate-cuneiform in lateral view. DM straight, VM convex, ends rounded, anterior broader. Greatest height anterior, LV larger, moderately overlapping RV along free margin. Valves bilobed, with a deep curved median sulcus extending anteroventrally. Surface regularly reticulated.

Material. 4 carapaces including 2 tecnomorphs and 2 heteromorphs.

Remarks. A distinct sexual dimorphism, characteristic of this species, is found here: tecnomorphs with a small projection at the ventral end of the front lobe (Pl. 6, figs. 3a-b), heteromorphs with 4 anteroventral loculi (Pl. 7, fig. 1).

Occurrence. Asbian to Brigantian of Great Britain, Upper Mississippian of U.S.A.

Suborder Kirkbyacopina Gründel, 1969, sensu Pokorný, 1978

Superfamily Kirkbyacea Ulrich & Bassler, 1906

Family Amphissitidae Knight, 1928

Genus *Amphissites* Girty, 1910

Subgenus *Amphissites* (*Amphissites*) Girty, 1910

Amphissites (*Amphissites*) *urei* (Jones, 1859)

(Fig. 5, Pl. 1, figs. 1-3)

1859 *Kirkbya urei* - Jones, p. 136 (not illustrated).

1870 *Kirkbya urei* - Jones, p. 185, Pl. 61, figs. 15a, b.

1885 *Kirkbya urei* - Jones & Kirkby, p. 189, Pl. 30, fig. 19.

1932 *Amphissites urei* - Latham, p. 369, fig. 16.

1978 *Amphissites urei* - Robinson, p. 144, Pl. 8, figs. 1a, b.

1982 *Amphissites urei* - Bless & Massa, p. 27, Pl. 1, fig. 5.

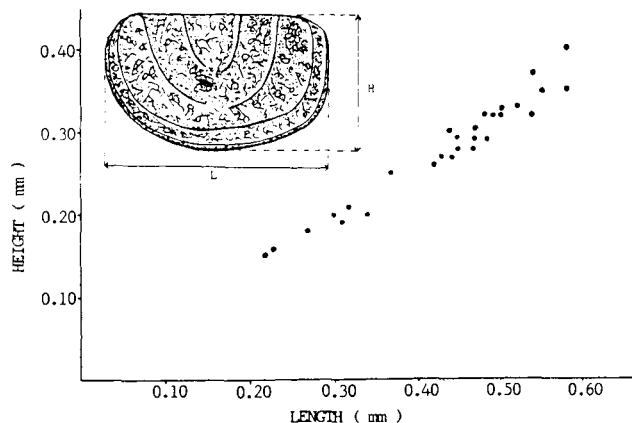


Fig. 5 Size distribution chart for 28 carapaces of *Amphissites urei*.

Explanation of Plate 2

Figs. 1-2 *Coronakirkbya cornuta* (Robinson, 1959).

Fig. 1a-b RGM 350.528, 560 cm L 0.56 mm, H 0.33 mm: fig. 1a, LV (x 1220); fig. 1b, detail of LV (x 400).

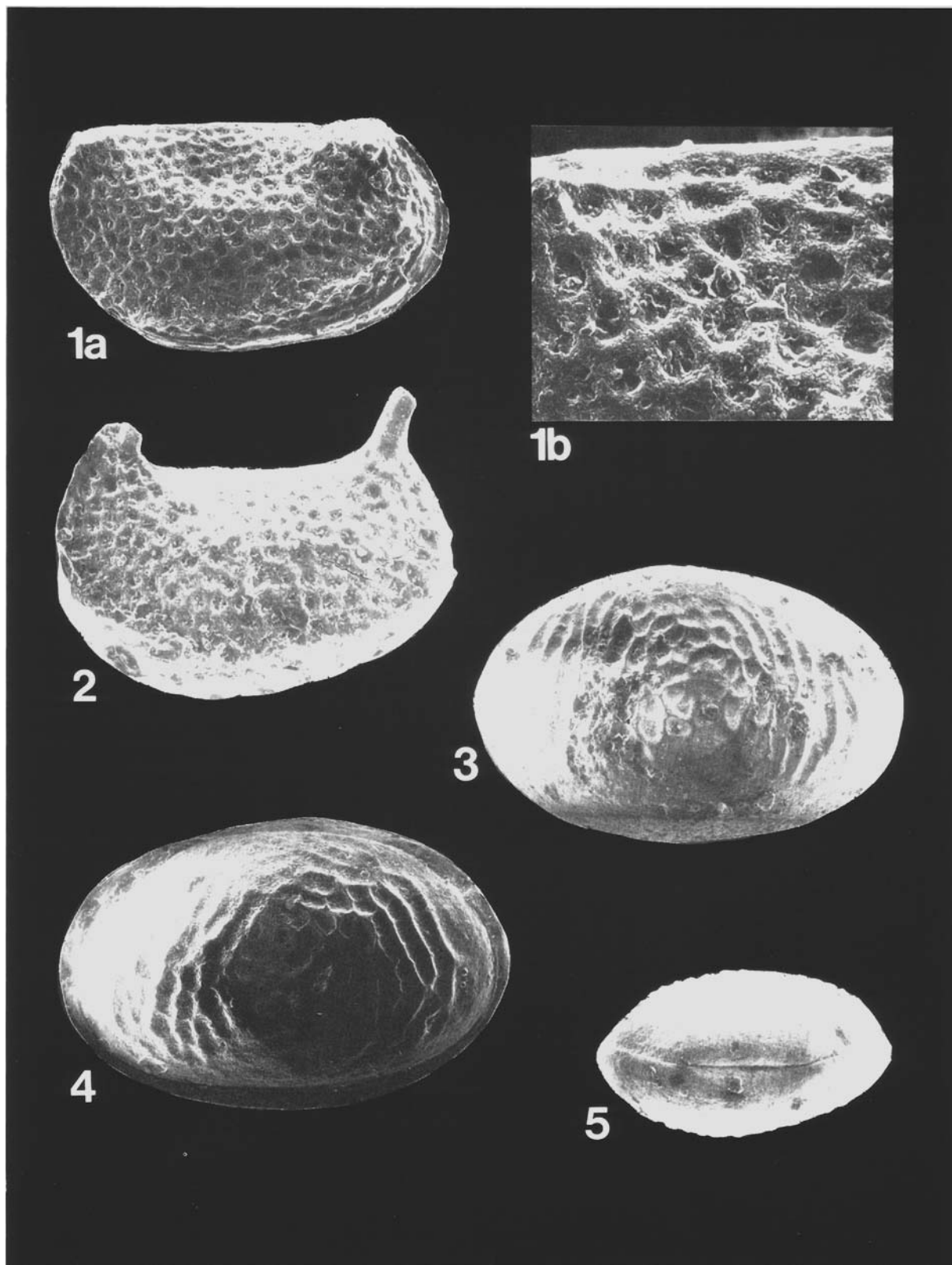
Fig. 2 RGM 350.529, 560 cm, LV, L 0.58 mm, H 0.34 mm (x 160)

Figs. 3-5 *Scrobicula scrobiculata* (Jones, Kirkby & Brady, 1884).

Fig. 3 RGM 350.540, 550 cm, LV, L 0.53 mm, H 0.34 mm (x 120).

Fig. 4 RGM 350.541, 540 cm, RV, L 0.51 mm, H 0.33 mm (x 120)

Fig. 5 RGM 350.542, 550 cm, dorsal view, L 0.53 mm, H 0.35 mm (x 80).



Diagnosis. Carapace oblong, rounded in lateral view, elongate subrectangular in dorsal view. Greatest length just above midline, hinge line straight. Surface reticulate, with a subcentral oval pit only observable on well preserved specimens. Three strong concentric carinae enclose an inner, more delicate V-shaped ridge, all attached to the marginal dorsal carina.

Material. About 50 carapaces and 5 valves.

Dimensions: See Fig. 5.

Remarks. Robinson (1978) noted that a study of the variation in the pattern of the carinae, particularly the inner one (which may be U-, V- or J-shaped), might justify further subdivision.

Occurrence. Holkerian to Arnsbergian of Great Britain, Lower Carboniferous of U.S.S.R. and Upper Carboniferous of Libya.

Genus *Kegelites* Coryell & Booth, 1933

Kegelites sp.

Material. 1 pyritised carapace

Description. Carapace oblong, small (L 0.25 mm, H 0.15 mm), subquadrate in lateral view. Hinge line straight, ends rounded, anterior broader. VM slightly concave medianally. Distinct marginal carina along free margin, posterior node projecting above hinge line. Surface finely reticulate.

Superfamily Kirkbyacea Ulrich & Bassler, 1906

Family Kirkbyidae Ulrich & Bassler, 1906

Genus *Kirkbya* Jones, 1859

Kirkbya quadrata Robinson, 1959

(Fig. 6, Pl. 1, figs. 4-5)

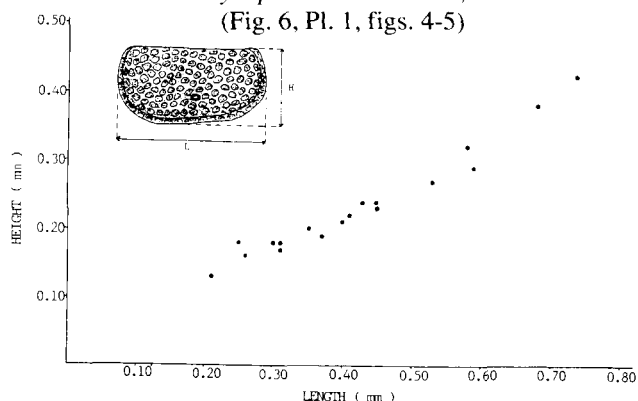


Fig. 6 Size distribution chart for 18 carapaces of *Kirkbya quadrata*.

1959 *Kirkbya quadrata* - Robinson, p. 437, Fig. 2: 4-5

1978 *Kirkbya quadrata* - Robinson, p. 142, Pl. 7, figs. 4a,b.

Diagnosis. Carapace quadrate in lateral outline, DM and VM almost straight. Elongate subrectangular in dorsal view, hinge line straight. Greatest length just above midline, valves subequal, slightly higher behind than in front. Surface regularly reticulated, reticulum being fairly large, with a subcentral kirkbyan pit and 2 marginal rims.

Material. About 40 carapaces and 8 valves.

Dimensions. See fig. 6.

Remarks. Many specimens are flattened and more or less distorted, due to compression in the sediment.

Occurrence: Upper Brigantian of Great Britain.

Genus *Coronakirkbya* Sohn, 1954

Coronakirkbya cornuta (Robinson, 1978)

(Pl. 2, figs. 1-2)

1978 ?*Coronakirkbya cornuta* - Robinson, p. 142, Pl. 7, figs. 1a-b.

Diagnosis. Carapace semicircular in lateral view, maximum height posterior of midline. DM straight, VM and ends rounded, cardinal angles obtuse. Two hollow spines rise from the cardinal angles, pointing slightly backwards. A central lobe is more or less strongly developed, carrying a kirkbyan pit. The inner of the two marginal carinae is somewhat irregular to the outline. Surface finely reticulate.

Material. 2 carapaces with damaged spines.

Remarks. The specimens described in this paper closely resemble ?*Kirkbya cornuta* illustrated by Robinson (1978, Pl. 7, figs. 1a,b). Robinson assigned his specimens with some doubt to the genus *Kirkbya*, because of the absence of a distinct central lobe. Nevertheless, it is suggested here that the central lobe, which is a diagnostic feature of *Coronakirkbya*, may sometimes be obscured by abrasion or may be less well developed, as illustrated by the specimens described in this paper. Other species of *Coronakirkbya* also often show some variation in the prominence of the central lobe, e.g. *C. krejci grafi* from the Upper Carboniferous of N. Spain (Becker, 1978: p. 57-58, Pl. 4, figs. 19-22).

Family Roundyellidae Gramm, 1976

Genus *Roundyella* Bradfield, 1935

Roundyella binoda sp. nov.

(Fig. 7, Pl. 1, figs. 1-5)

Explanation of Plate 3

Figs. 1-5 *Roundyella binoda* n. sp.

Fig. 1 RGM 350. 530, holotype, 500 cm, LV, L 0.45 mm, H 0.25 mm (x 140).

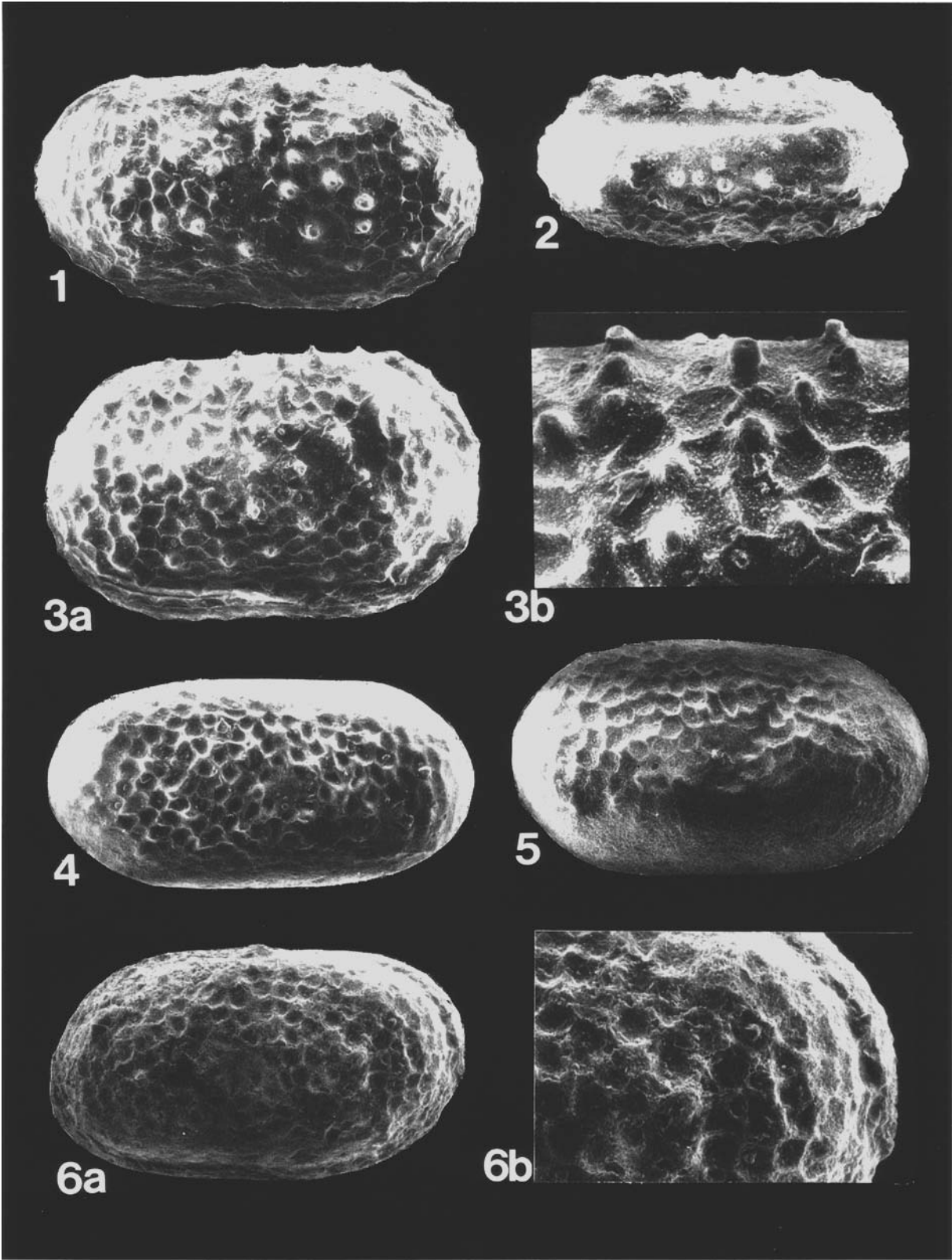
Fig. 2 RGM 350. 531, paratype, 500 cm, dorsal view, L 0.38 mm, H 0.22 mm (x 140).

Figs. 3a-b RGM 350. 532, paratype, 560 cm, L 0.41 mm, H 0.26 mm: fig. 3a, LV (x 140); fig. 3b, detail of LV (x 400).

Fig. 4 RGM 350. 533, 540 cm, RV, L 0.42 mm, H 0.25 mm (x 140).

Fig. 5 RGM 350. 534, 540 cm, RV, L 0.40 mm, H 0.25 mm (x 140).

Figs. 6a-b *Eriella minima* n. sp., RGM 350. 635, holotype, 200 cm, L 0.44 mm, H 0.25 mm: fig. 6a, LV (x 160); fig. 6b, detail of LV (x 320)



Derivation of name. Latin, referring to the presence of 2 node-like posterodorsal spines.

Diagnosis. Carapace oblong, subquadrate in lateral outline. DM straight, VM Straight or slightly concave, ends almost equally rounded. Inequivalved, RV overlapping LV. Hinge line straight, hinge slightly impressed. Surface ornamented with a regular reticulation and scattered spines/papillae, and a small but distinct node-like spine in the posterodorsal area of each valve, a subcentral smooth muscle spot.

Holotype. RGM 350.530 (Pl. 1, fig. 1)

Paratypes. RGM 350.531, 350.532 (Pl. 1, figs. 2, 3).

Material. More than 150 carapaces.

Type locality. See fig. 2. It corresponds to locality 55 of Moore (1958) and section 5 of Masurel (1987: fig. 1) in Bishopdale, northern England.

Dimensions. See fig. 7.

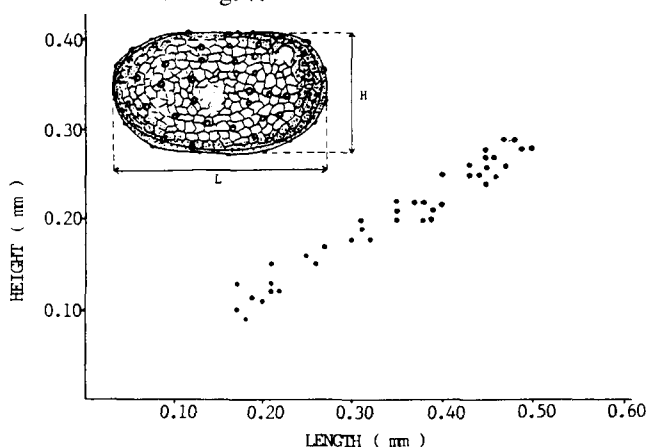


Fig. 7 Size distribution chart for 40 carapaces of *Roundyella binoda* n. sp.

Remarks. This new species has similarities in shape and surface ornament to *R. reticulosa* (Jones & Kirkby, 1886) and *R. simplicissima* (Knight, 1928). It is distinguished by the presence of two relatively larger posterodorsal spines observable in dorsal view (Pl. 1, fig. 2), and which are already prominent in early instars. *R. dorsopapillosa* Sohn (1954, p. 19, Pl. 1, figs. 20-26) is another species with posterodorsal spines. The latter is considerably larger and has a greater number of spines scattered on the surface.

Family Scrobiculidae Posner, 1951

Genus *Scrobicula* Posner, 1951

Scrobicula scrobiculata (Jones, Kirkby & Brady, 1884)

(Fig. 8, Pl. 2, figs. 4-6)

1884 *Cytherella scrobiculata* - Jones, Kirkby & Brady, 1884, P. 76-77, Pl. 6, fig. 10.

1951 *Scrobicula scrobiculata* - Posner, p. 53, Pl. 10, fig. 3.

1978 *Scrobicula scrobiculata* - Robinson p. 148, Pl. 10, figs. 3a,b.

Diagnosis. Carapace oval-oblong, ends almost equally rounded. Inequivalved, LV overlapping RV. Hinge line straight, hinge slightly impressed. Surface ornamented with a strong "fingerprint" reticulation, relatively longer meshes tend to be concentric.

Material. About 100 carapaces.

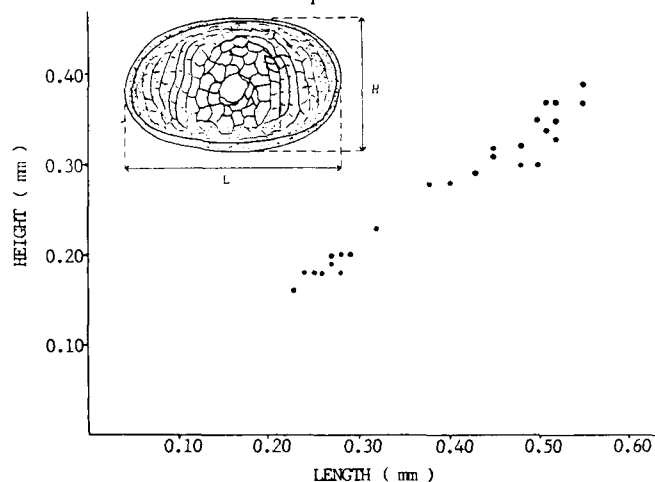


Fig. 8 Size distribution chart for 26 carapaces of *Scrobicula scrobiculata*.

Dimensions. See fig. 8

Remarks. A study of variations in the reticulate pattern of this species might lead to further subdivision.

Occurrence: Brigantian of Great Britain, Lower Carboniferous of U.S.S.R.

Superfamily Primitiopsacea Swartz, 1939

Family Graviidae Polenova, 1952

Genus *Coryellina* Bradfield, 1935

Coryellina cf. *reticosa* (Jones & Kirkby, 1886)

(Pl. 7, fig. 2)

Explanation of Plate 4

Figs. 1-4 *Cribricooncha caneyensis* (Harlton, 1927).

Fig. 1. RGM 350. 582, 550 cm, LV, L 0.60 mm, H 0.33 mm (x 120)

Fig. 2 RGM 350. 583, 550 cm, RV, interior, L 0.59 mm, H 0.35 mm (x 120).

Fig. 3 RGM 350. 584, 25 cm RV, L 0.63 mm, H 0.38 mm (x 120).

Fig. 4 RGM 350. 585, 25 cm, dorsal view, L 0.59 mm, H 0.35 mm (x 120).

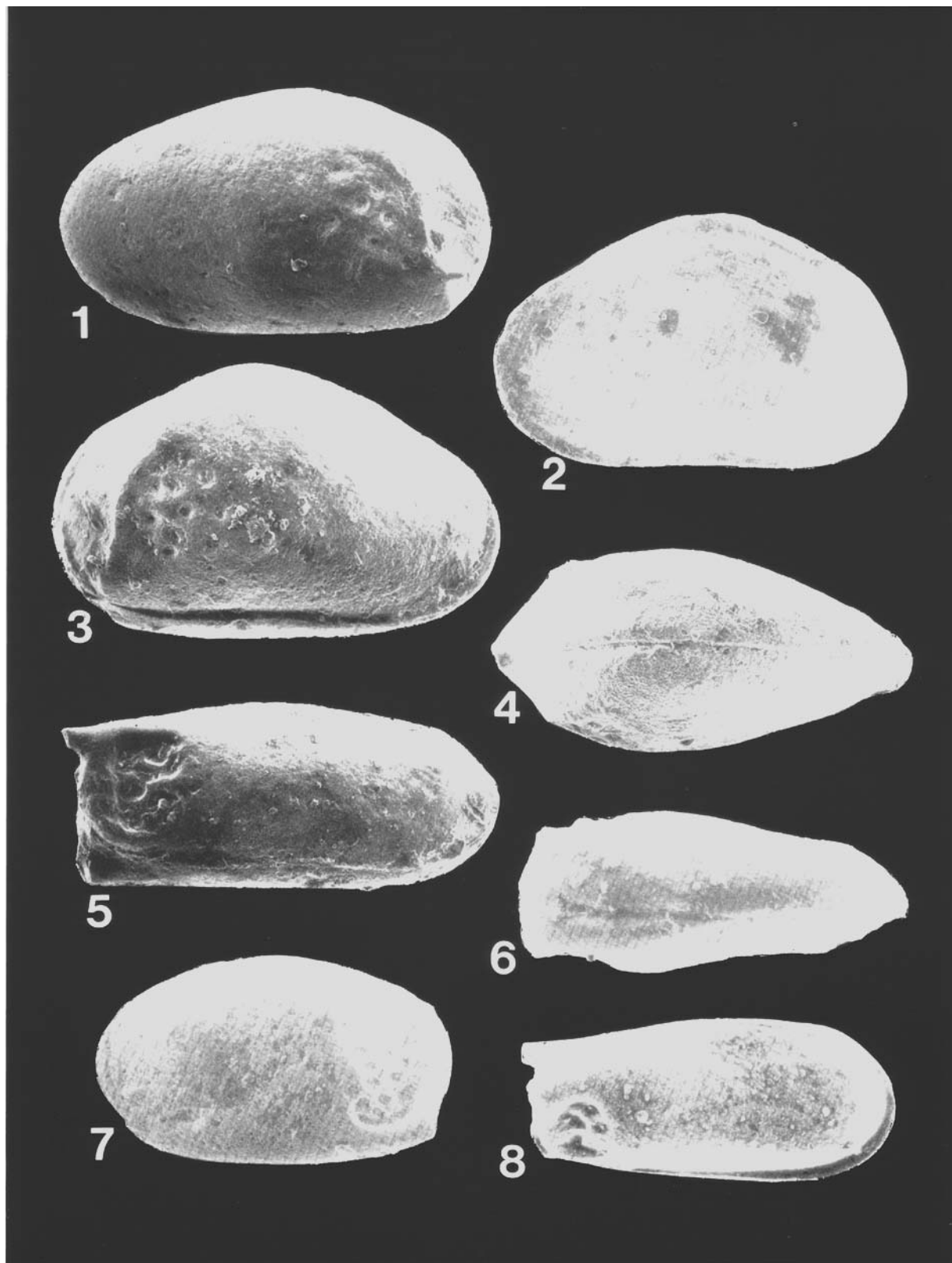
Figs. 5-8 *Cribricooncha insculpta* Robinson 1959.

Fig. 5 RGM 350. 572, 25 cm, RV, L 0.50 mm, H 0.22 mm (x 140).

Fig. 6 RGM 350. 573, 550 cm, dorsal view, L 0.51 mm, H 0.23 mm (x 120).

Fig. 7 RGM 350. 574, 540 cm, LV, L 0.50 mm, H 0.28 mm (x 120).

Fig. 8 RGM 350. 575, 540 cm, RV slightly oblique, L 0.51 mm, H 0.23 mm (x 120).



Diagnosis. Carapace obliquely subovate in lateral outline. DM straight, VM arched, ends rounded, posterior broader. Valves almost equal, RV larger. Surface regularly reticulate, median sulcus anterior of mid-length.

Material. 1 carapace.

Description. A deep median sulcus marks the finely reticulate surface, with an obscure node behind and a more clearly developed lobe in front of the sulcus. Small spines are scattered in the posteroventral area, and there is a larger posteroventral spine (broken off in the material examined).

Remarks. Robinson (1978) described this species from the Pendleian of Great Britain, and illustrated it with a specimen with a slightly weaker median sulcus.

Occurrence. *C. reticosa* is recorded from the Pendleian to lower-most Arnsbergian of Great Britain (Robinson, 1978).

Suborder Kirkbyocopina?

Superfamily Youngiellacea Kellet, 1933

Family Youngiellidae Kellet, 1933

Genus *Moorites* Coryell & Billings, 1932

Moorites elongatus (Jones & Kirkby, 1886)

Pl. 7, fig. 6

1886 *Cytherella* (?) *elongata* - Jones & Kirkby, p. 262-263, Pl. 9, figs. 2-3.

1941 *Moorites elongatus* - Cooper, p. 20, Pl. 1., figs. 3a-b.

Diagnosis. Carapace elongate, slightly oblique in lateral view. Maximum height anteriorly, ends rounded. DM straight and long, VM straight or flatly convex. LV larger, moderately overlapping along the entire margin. Marginal rims obscure, most prominent along the anterior end.

Material. 5 carapaces.

Description. See diagnosis. Pits have been detected in undefined depressions bordering the anterior and more obscure posterior marginal rim, and scattered on the rest of the surface. The marginal rim, particularly the anterior, appears to have been best developed in the adult stages.

Occurrence. Lower Carboniferous of Great Britain.

Order Myodocopida Sars, 1866

Suborder Cladocopina Sars, 1866

Family Polycopidae Sars, 1866

Genus *Discoidella* Croneis & Gale, 1939

Discoidella sp.

? 1959 *Discoidella* cf. *convexa* - Robinson, p. 437, fig. 2: 1-

2.

Material. 6 poorly preserved carapaces.

Diagnosis: Carapace subcircular in lateral view, greatest width above mid-height. Hinge short, straight and depressed below DM. Surface ornamented by very faint concentric striae, more or less parallel to the free margin.

Order Metacopida Sylvester-Bradley, 1961

Superfamily Healdiacea Harlton, 1934

Family Healdiidae Harlton, 1933

Genus *Cribroconcha* Cooper, 1941

Cribroconcha caneyensis (Harlton, 1927)

(Fig. 9, Pl. 4, figs. 1-4.)

1927 *Healdia caneyensis* - Harlton, p. 207, fig. 3.

1947 *Healdia caneyensis* - Cooper, Pl. 22, figs. 5-7.

? 1977 *Healdia* ex gr. *H. caneyensis* - Sohn, p. 150, Pl. 2, figs. 4-5

Diagnosis. Carapace subovate to subtriangular in lateral view, maximum height posterior, maximum width central. LV overlapping RV along the entire margin. DM arched, VM almost straight, ends rounded, anterior narrower. Posteriorly, a curved, almost vertical posterior ridge, concave anteriorly, is terminated both dorsally and ventrally by small, posteriorly directed spines. A slightly depressed pit-field with scattered circular pits borders the inner, anterior side of the ridge. Otherwise smooth.

Material. About 100 carapaces and 15 valves.

Dimensions. See Fig. 9.

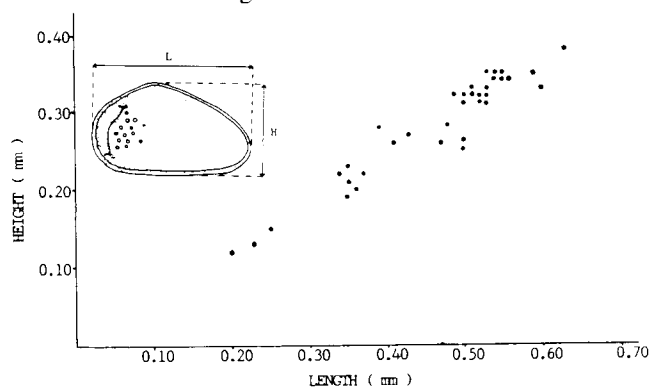


Fig. 9 Size distribution chart for 35 carapaces of *Cribroconcha caneyensis*.

Explanation of Plate 5

Figs 1-2 *Cribroconcha perplexa* Robinson 1959.

Fig. 1 RGM 350.576, 920 cm, RV, L 0.65 mm, H 0.33 mm (120).

Fig. 2 RGM 350.577, 920 cm, RV, L 0.68 mm, H 0.35 mm (x 100).

Figs 3-7 *Healdianella* cf. *darwinoides* Posner, 1951.

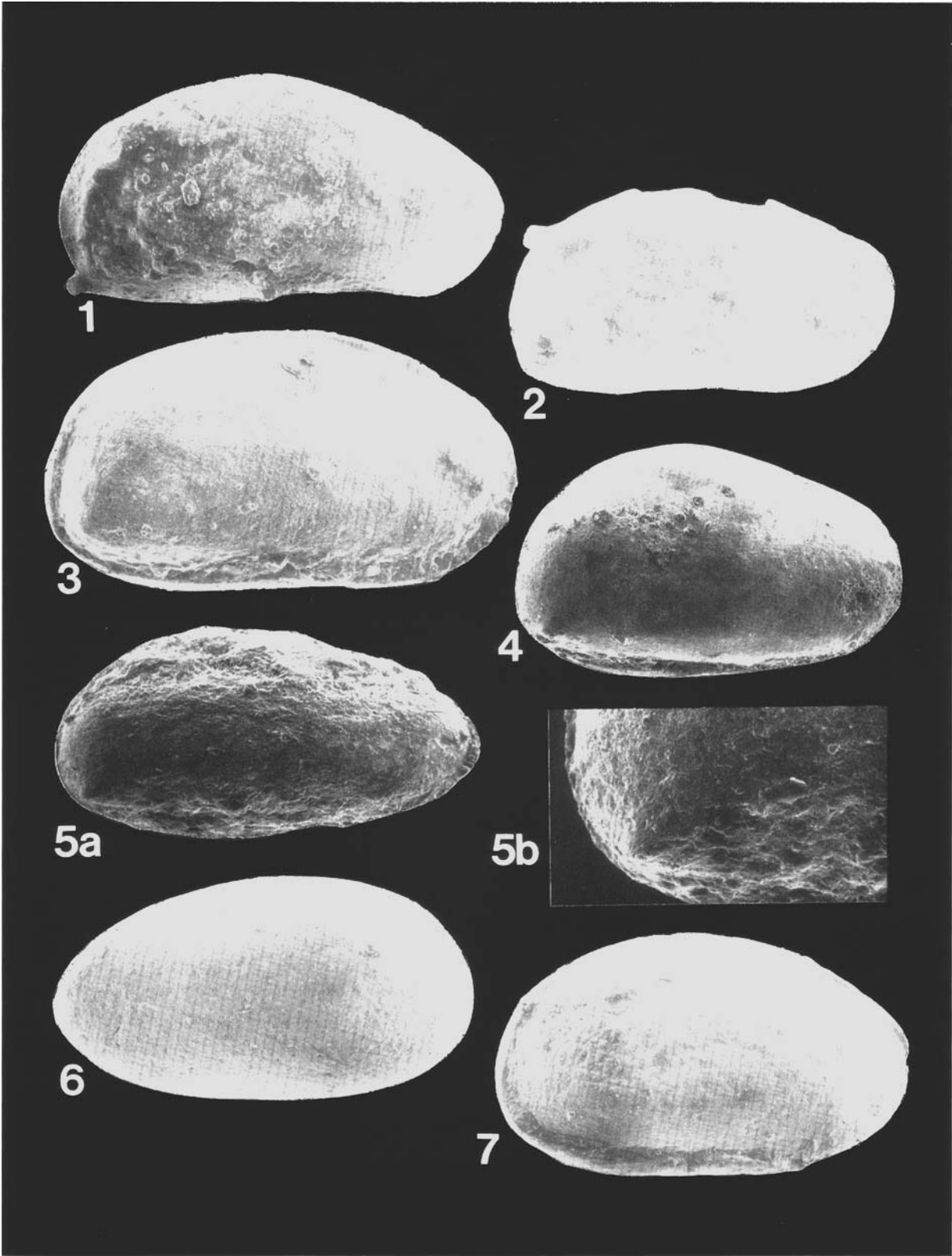
Fig. 3 RGM 350.593, 25 cm RV, L 0.42 mm, H 0.22 mm, tectomorph (x 200).

Fig. 4 RGM 350.594, 200 cm, RV, L 0.43 mm, H 0.25 mm, tectomorph (x 160).

Figs. 5a-b. RGM 350.595, 190 cm, L 0.46 mm, H 0.23 mm, tectomorph: fig. 5a, RV (x 160); fig. 5b, detail of RV (x 400).

Fig. 6 RGM 350.596, 560 cm, heteromorph, LV, L 0.61 mm, H 0.33 mm (x 120).

Fig. 7 RGM 350.597, 550 cm heteromorph, RV, L 0.62 mm, H 0.36 mm (x 120).



Remarks. The assignment of this species to the genus *Cribroconcha* is based on the presence of a pit-field anterior of the posterior ridge (Sylvester-Bradley in Moore, 1961, p. 361). It is probably conspecific with *Healdia* sp. ex gr. *H. caneyensis* recorded from the Upper Mississippian of northern Arkansas (Sohn, 1977). The latter only differs in that the posterior ridge is straight which may be a geographic variation.

Occurrence. So far only recorded from the Upper Mississippian of U.S.A., this is the first record from Great Britain.

Cribroconcha insculpta Robinson, 1959

(Fig. 10, Pl. 4, figs. 5-8)

1959 *Cribroconcha?* *insculpta* - Robinson, p. 443,

Fig. 1: 4a-c.

1978 *Cribroconcha insculpta* - Robinson, p. 144, Pl. 8, figs. 3a,b.

Diagnosis. Carapace elongate in lateral and dorsal view, DM convex, VM straight or slightly convex. Greatest height central, greatest width posterior of midline. Inequivalved, LV overlapping RV. Surface smooth, marked by a vertical posterior ridge which is concave anteriorly. A coarsely pitted, reticulated depression borders the inner, anterior side of the ridge, which is terminated both dorsally and ventrally by strong, backward-produced spines.

Material. 35 carapaces.

Dimensions. See fig. 10.

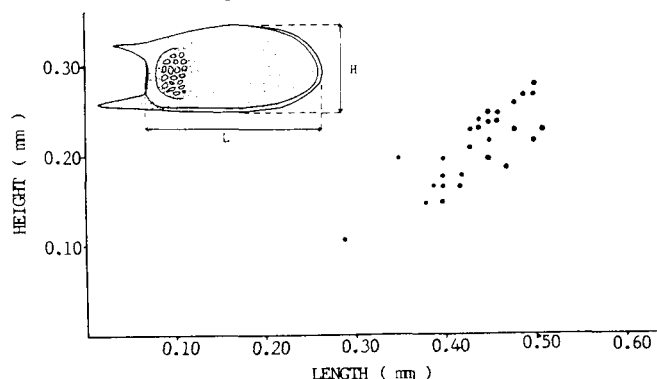


Fig. 10 Size distribution chart for 29 carapaces of *Cribroconcha insculpta*.

Remarks. *Cribroconcha insculpta* shows some variation in the length/height ratio (fig. 10), which is ascribed to sexual dimorphism: The first form, characterised by a greater height and a more symmetrically convex dorsal outline (Pl. 10, fig. 7), and the second, relatively lower form with the

greatest thickness posterior of mid-length (Pl. 10, figs. 5, 6 and 8), are respectively interpreted as female and male.

Occurrence. Brigantian of Great Britain.

Cribroconcha perplexa Robinson, 1959

(Pl. 5, figs. 1-2.)

1959 *Cribroconcha perplexa* - Robinson, p. 442,

Fig. 1: 3a-c.

1978 *Cribroconcha perplexa* - Robinson, p. 144, Pl. 8, figs. 5a,b.

Diagnosis. Carapace elongate, DM convex, VM slightly concave. Ends rounded, anterior narrower, maximum height and width central. Surface smooth, marked by an anterior marginal flange and a vertical ridge near the posterior margin of each valve. The ridge is concave anteriorly, with two backward pointing spines at the dorsal and ventral ends. The ventral spine points slightly downwards, the dorsal slightly upwards. A pit-field with small, irregularly spaced pits borders the anterior side of the ridge.

Material. 5 carapaces and 6 partly damaged valves.

Occurrence. Brigantian of Great Britain.

Genus *Healdianella* Posner, 1951

Healdianella cf. *darwinuloides* Posner, 1951

(Fig. 11, Pl. 5, figs. 3-7.)

Diagnosis. Carapace elongate-ovate to subtriangular in lateral view. Maximum height and width at, or just posterior of mid-length. DM convex, VM straight or slightly convex. LV larger, overlapping RV. Surface generally smooth, occasional faint reticulation at posterior.

Material. 45 carapaces and 2 valves.

Dimensions. See fig. 11.

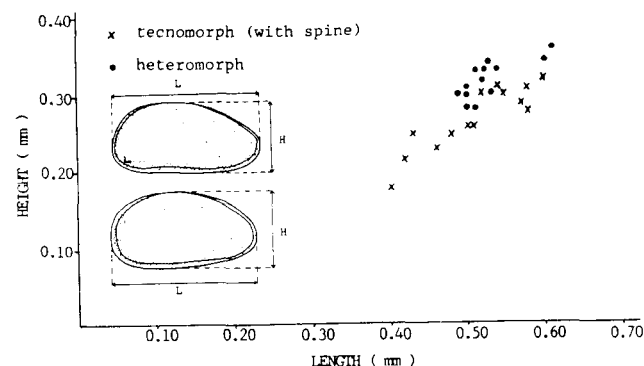


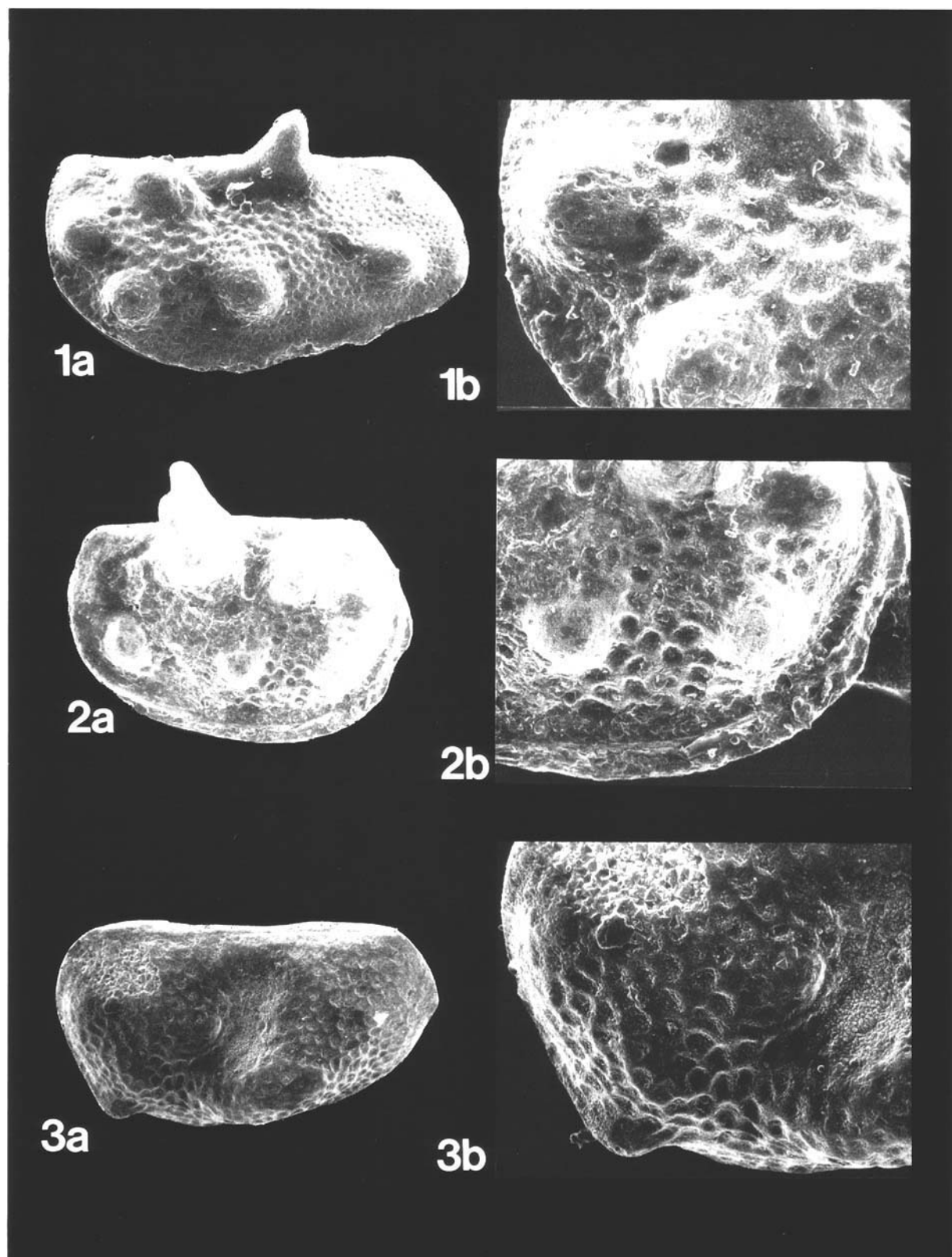
Fig. 11 Size distribution chart for 27 carapaces of *Healdianella* cf. *darwinuloides*.

Explanation of Plate 6

Figs 1a-b *Cornigella posteroextensa* n. sp., RGM 350. 505, holotype, 540 cm, L 0.59 mm, H 0.30 mm: fig. 1a, LV (x 160); fig. 1b, detail of LV (x 400).

Figs 2a-b *Cornigella tuberculospinosa* (Jones & Kirkby, 1886), RGM 350. 501, 500 cm, L 0.49 mm, H 0.32 mm: fig. 2a, RV (x 120); fig. 2b, detail of RV (x 240).

Figs. 3a-b *Tetrasacculus mirabilis* (Cronies & Galke, 1938), RGM 350.512, 540 cm, L 0.65 mm, H 0.32 mm tecnomorph: fig. 3a, LV (x 100); fig. 3b, detail of LV (x 200).



Remarks. The lenticular and transversely stretched meshes of the reticulation pattern, which is sometimes visible in the posterior area, are similar to those illustrated by Gramm (1982, Pl. 2, fig. 7, Pl. 3, fig. 4). This author suggested that in a related species ("*Healdia cornuta*" Posner, 1951) the posteroventral spine, which is usually found on right valves only, may be a larval adaption that is sometimes retained into the adult stage. In this study, the presence of a posteroventral spine is confined to early instars and males (tecnomorphs), which are distinguished from females (heteromorphs) by a less symmetrically rounded, generally more elongated shape (fig. 11). The tecnomorphs illustrated in Plate 5, figs. 3-5, resemble *Healdianella darwinuloides* Posner (Gramm, personal communication).

The subcircular adductor muscle scar is sometimes faintly visible just to the postero-ventral of centre.

Occurrence. *Healdianella darwinuloides* has been recorded from Visean strata of U.S.S.R. (Posner, 1951; Gramm, 1982). Species with affinities have been described from the Visean of France (Crasquin, 1987, Pl. 11, figs. 9a,b) and Mississippian of U.S.A. (Dewey, 1987, Pl. 6, figs. 9-11).

Order Podocopina Muller, 1894

Suborder Bairdiocopina Gründel, 1967 (sensu 1978)

Superfamily Bairdiacea Sars, 1888

Family Bairdiidae Sars, 1888

Subfamily Bairdiinae Sars, 1888

Genus *Bairdiacypris* Bradfield, 1935

Bairdiacypris subelongata (Jones & Kirkby, 1879)

(Pl. 8, figs. 6-7)

1879 *Bairdia subelongata* - Jones & Kirkby, p. 573, Pl. 30, Figs. 1-5

1960 *Bairdiacypris subelongata* - Sohn, p. 59.

Diagnosis: Carapace elongate, DM and VM subparallel, DM convex, VM almost straight. LV larger, overlapping along free margin. Posterodorsal slope slightly concave, ending in a blunt posterior end below mid-height. Anterior end broadly rounded. Surface smooth.

Material. 9 carapaces and 23 recognisable fragments.

Remarks. Jones & Kirkby (1886, 1892) and other authors, e.g. Vine (1884) and Harlton (1927, 1929) have assigned different species to *B. subelongata* (see Sohn, 1960, p.59)

Occurrence. Carboniferous of Great Britain.

Bairdiacypris sp. aff. *B. robusta* Kummerow, 1939

(Pl. 8, fig. 5.)

Diagnosis. Carapace elongate, subrectangular in lateral

view. DM gently convex, VM sharply concave. Ends broadly rounded, maximum width posterior to mid-length. LV larger, overlapping RV. Surface smooth.

Materials. 1 carapace.

Occurrence. The specimen shows affinities to *Bairdiacypris* aff. *robusta* described from Lower Tournaisian strata of Belgium (Becker & Bless, 1974) and late Dinantian Carbonates of N. Belgium (Bless et al., 1981), and *B. quasielongata* Bushmina, 1968 from the Tournaisian of U.S.S.R. (Bless et al., 1981, p. 150, Pl. 3, figs. 55-57).

Bairdiacypris cf. *curvis* (Cooper, 1941)

Diagnosis. Carapace small, elongate, Concavity of VM distinct, slightly anterior to mid-length. DM gently convex, ends rounded. Surface smooth.

Material. 1 poorly preserved carapace.

Occurrence. *Bairdiacypris curvis* has been recorded from the Upper Mississippian of U.S.A. (Cooper, 1941, p. 25, Pl. 1, figs. 43-44; Sohn, 1960, p. 58, Pl. 2, figs. 11-13).

Genus *Bairdia* McCoy, 1844

Bairdia beedei Ulrich & Bassler, 1906

(Pl. 9, fig. 5)

1906 *Bairdia beedei* - Ulrich & Bassler, p. 161, Pl. 11, figs. 19-20.

Diagnosis. Carapace subelongate, dorsum convex, venter almost straight. Posterior end acuminate, anterior end broadly rounded above mid-length. LV larger, moderately overlapping RV along the entire margin. Anteroventral margin gently convex, anterodorsal margin straight. Posteroventral margin slightly convex, posterodorsal margin more strongly convex. Dorsal outline ovate, sides evenly rounded, sloping towards anterior and posterior ends. Surface pitted.

Material. 2 carapaces and 1 valve.

Occurrence. Lower Pennsylvanian to Permian of U.S.A. (Sohn, 1960); Pendleian to Arnsbergian of Great Britain (Robinson, 1978). This is the first record from strata older than Pendleian. See Sohn (1960, p. 23) for full synonymy.

Bairdia harltoni Cooper, 1946

(Pl. 9, figs. 7-8.)

1946 *Bairdia harltoni* - Cooper, p. 45, Pl. 2, figs. 30-31.

(For synonymy list see Sohn, 1960, p. 27).

Diagnosis. Carapace subdeltoid in lateral view, dorsum boldly convex, venter straight or slightly convex. Sinuous antero- and posterodorsal margins, anterior margin with

Explanation of Plate 7

Figs. 1a-b *Tetrasacculus mirabilis* (Croneis & Gale, 1938), RGM 350. 514, 25 cm, L 0.67 mm, H 0.38 mm heteromorph: fig.

1a, RV (x 100); fig. 1b, detail of RV (x 240).

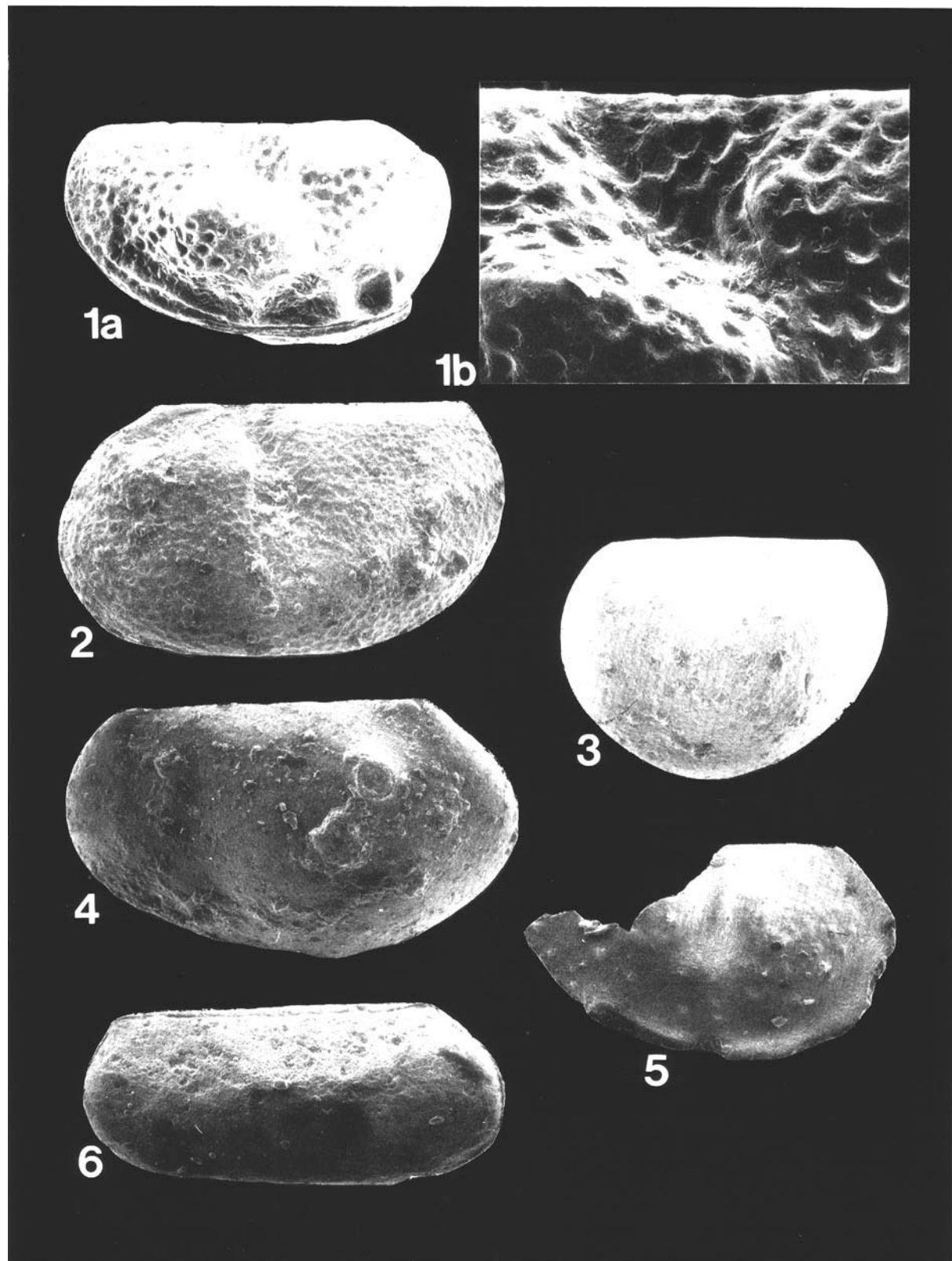
Fig. 2 *Coryellina* cf. *reticosa* (Jones & Kirkby, 1886), RGM 350. 547, 870 cm, LV L 0.82 mm, H 0.49 mm (x 80).

Fig. 3 *Shishaella* cf. *williamsae* Sohn, 1971, RGM 350.630, 870 cm, LV L 0.57 mm H 0.42 mm (x 100).

Fig. 4 *Shivaella armstrongiana* (Jones & Kirkby, 1886), RGM 350. 634, 895 cm, LV L 0.98 mm, H 0.65 mm (x 80).

Fig. 5 *Hollinella radiata* (Jones & Kirkby, 1886), RGM 350.511, 560 cm, fragment of RV (x 60).

Fig. 6 *Moorites elongatus* (Jones & Kirkby, 1886), RGM 350, 548, 540 cm, RV, L 0.39 mm, H 0.17 mm).



broadly rounded extremity above mid-height, and a posterior, bluntly pointed extremity below mid-height. Antero- and posteroventral margins convex. Surface smooth.

Material. 2 carapaces.

Occurrence. Carboniferous of Great Britain and U.S.A. (Sohn, 1960)

Genus *Rectobairdia* (Sohn, 1960)

Remarks. Some authors consider *Rectobairdia* as a genus (e.g. Sohn, 1960 and Bless et al., 1981) or a subgenus of *Bairdia* (e.g. Crasquin, 1984)

Rectobairdia bavarica sp. nov.

(Fig. 12)

1865 *Bairdia hisingeri* - Jones & Kirkby, p. 408, Pl. 20, figs. 12a-c.

?1960 *Rectobairdia* sp. E - Sohn, p. 56.

Derivation of name. After Bavaria. Specimens of this species that were obtained from the Carboniferous Limestone at Regitzlosan, near Hof in Bavaria, Germany, were described by Jones & Kirkby (1865), and, together with several different species, assigned to *Bairdia hisingeri* (Münster, 1830).

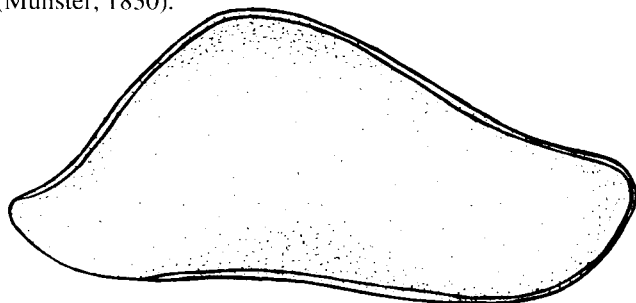


Fig. 12 *Rectobairdia bavarica* n. sp. (outside right valve; 25x).

Diagnosis. Carapace subelongate, DM highly arched, VM slightly concave medially, ends acuminate. Posterodorsal slope steep and flatly concave, anterodorsal margin longer and slightly concave. Posterior end bluntly pointed below mid-height, anterior end broader. Antero- and posteroventral margins convex. Maximum height posterior to mid-length, maximum width central. Surface smooth.

Holotype. RGM 350.611

Paratype. RGM 350.612

Material. 1 carapace and 1 valve.

Type locality. See Fig. 2. It corresponds to locality 55 of Moore (1958) and section 5 of Masurel (1987: fig. 1) in Bishopdale, northern England.

Remarks. The various species that have been assigned to *Bairdia hisingeri* (Münster, 1830), including this one, were later separated by Sohn (1960).

Occurrence. Carboniferous of Germany and Great Britain.

Genus *Bairdiolites* Croneis & Gale, 1939

Bairdiolites elevatus Robinson, 1959

(Pl. 9, figs. 1-4.)

1959 *Bairdiolites elevatus* - Robinson, p. 441, Fig. 1: 1a.c.

1978 *Bairdiolites elevatus* - Robinson, p. 154, Pl. 13, figs. 4a-b.

Material. 9 carapaces.

Occurrence. Upper Brigantian of Great Britain.

Family Bairdiocypridae Shaver, 1961

Genus *Bairdiocypris* Kegel, 1932

Bairdiocypris fomikhaensis Bushmina, 1968

(Pl. 8, figs. 3-4.)

1968 *Bairdiocypris fomikhaensis* - Bushmina, p. 95, Pl. 6, fig. 5, Pl. 17, figs. 1-3, Pl. 18, fig. 1.

1970 *Bairdiocypris fomikhaensis* - Bushmina, p. 29, Pl. 8, figs. 1-3.

1975 *Bairdiocypris fomikhaensis* - Bushmina, p. 53, Pl. 8, fig. 3.

? 1981 *Bairdiocypris* cf. *rudolphi* - Bless et al., p. 150-151, Pl. 4, figs. 58-61.

1984 *Bairdiocypris fomikhaensis* - Crasquin, p. 62, Pl. 8, fig. 10.

1987 *Bairdiocypris fomikhaensis* - Crasquin, p. 56, Pl. 10, figs. 8-11.

Diagnosis. Carapace subtriangular in lateral view, DM of right valve gently angular, LV overlapping. Maximum height just anterior to mid-length. VM gently concave, ends rounded, anterior slightly narrower and pointed in dorsal view. Surface smooth.

Material. 9 carapaces and 11 single valves or fragments.

Remarks. *B. fomikhaensis* has not been recorded from British strata before. The specimens that are illustrated in this paper closely resemble those described from Lower Tournaisian to Upper Viséan strata of France (Crasquin, 1984, 1987), and from the Tournaisian of Russia (Bushmina,

Explanation of Plate 8

Fig. 1 *Cavellina* cf. *benniei* (Jones, Kirkby & Brady, 1884), RGM 350. 638, 25 cm, LV, L 0.74 mm, H 0.34 mm (x 100).

Fig. 2 *Cryptophyllus* sp., RGM 350.553, 25 cm, L 0.57 mm, H 0.42 mm (x 120).

Figs. 3-4 *Bairdiocypris fomikhaensis* Bushmina, 1968.

Fig. 3 RGM 350. 620, 870 cm, RV, L 0.80 mm, H 0.46 mm (x 100).

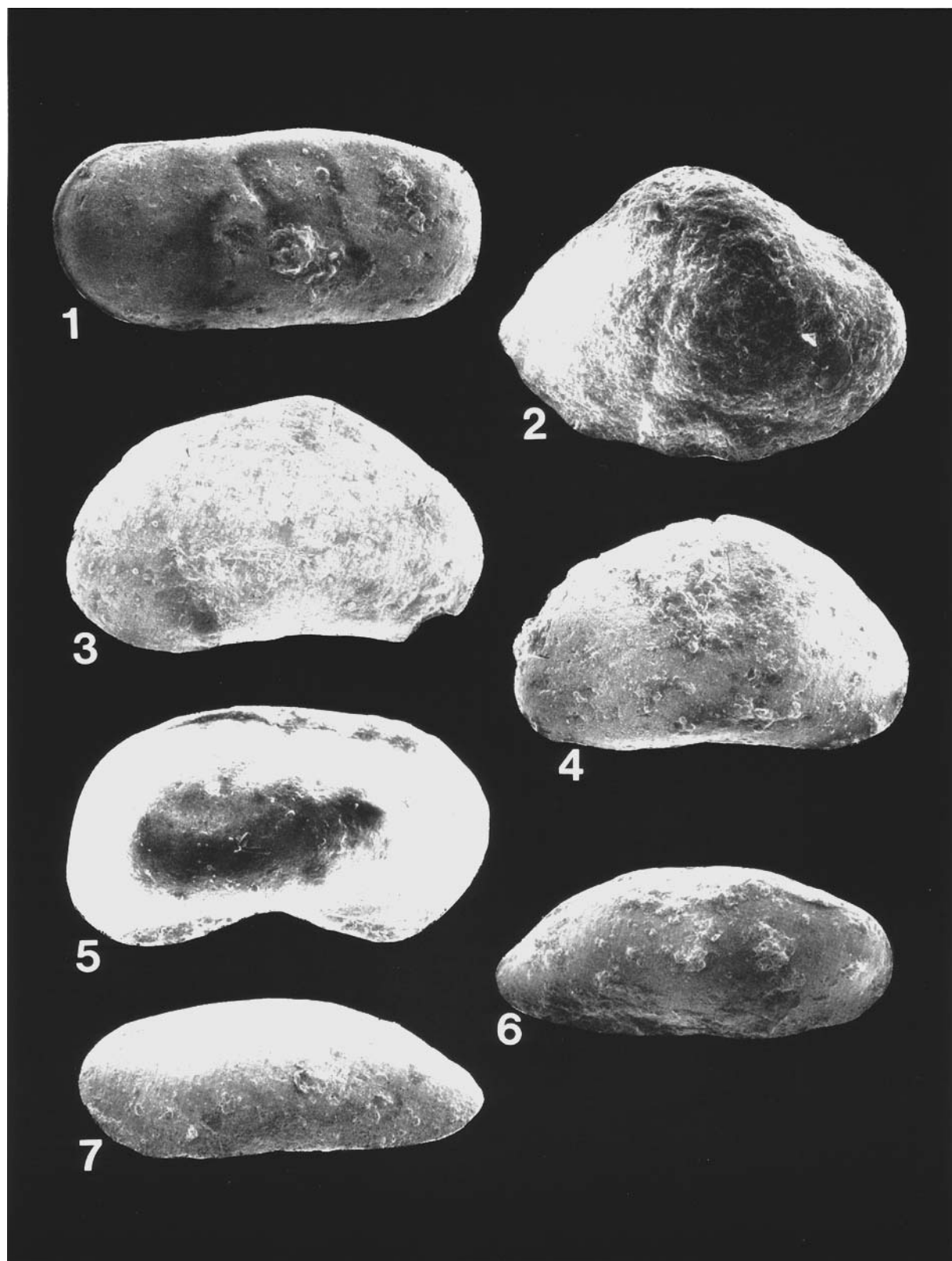
Fig. 4 RGM 350. 621, 920 cm RV L 0.45 mm, H 0.32 mm (x 120).

Fig. 5 *Bairdiocypris* sp. aff. *robusta* Kummerow, 1939, RGM 350. 606, 550 cm, RV, L 0.52 mm, H 0.26 mm (x 100)

Figs. 6-7 *Bairdiocypris subelongata* (Jones & Kirkby, 1879).

Fig. 6 RGM 350.598, 845 cm LV, L 1.23 mm, H 0.51 mm (x 55).

Fig. 7 RGM 350, 599, 870 cm, RV, L 1.25 mm, H 0.49 mm (x 55)



1968, 1970, 1975). Bless et al. (1981) suggested a close relationship with *Bairdiocypris* cf. *rudolphi* (Kummerow, 1939) from the uppermost Famennian to Upper Visean of Belgium (Becker & Bless, 1974) and late Dinantian Carbonates of N. Belgium (Bless et al., 1981), also with *B. bilobatus* (Münster, 1830) sensu Kummerow, 1939 from the Lower Visean of Belgium and Germany (Becker & Bless, 1974).

Suborder Cytherocopina Gründel, 1967

Superfamily Cytheracea Baird, 1850

Family Bythocytheridae Sars, 1926

Genus *Monoceratina* Roth, 1928

Monoceratina antiqua (Jones & Kirkby, 1886)

1886 *Bythocythere antiqua* - Jones & Kirkby, p. 263, Pl. 9, figs. 5a,b.

1956 *Monoceratina antiqua* - Posner in Zanina, p. 194-195, Pl. 1, fig. 3.

1978 *Monoceratina antiqua* - Robinson, p. 140, Pl. 6, figs. 4a,b.

1983 *Monoceratina antiqua* - Dewey, p. 113, fig. 6J.

? 1977 *Monoceratina* ? sp. - Sohn, p. 150, Pl. 2, fig. 17.

1987 *Monoceratina antiqua* - Dewey & Fähræus, p. 105, Pl. 4, figs. 17-20.

Diagnosis. Carapace subrhomboidal in lateral view, tumid. DM long and straight, VM convex, anterior end broadly convex. Posterior end flatly convex, projecting above. Cardinal angles obtuse, marginal rim distinct along anterior and posterior margins, narrow along VM. Wing-like expansions or alae, most developed posteriorly, with a dorsoventral, backwards pointing thorn-like spine on each valve. Median sulcus faint, extending to centre of valve. Surface pitted.

Material. 1 carapace.

Occurrence. Summarised by Dewey (1987): Newfoundland, Great Britain, U.S.S.R., U.S.A. The range of this species, known from Chadian to Asbian strata of Great Britain (Robinson, 1978), is now extended to the Upper Brigantian stage. Dewey (1987) also suggested a possible extension of the species range to the Upper Chesterian of the Midcontinent of U.S.A.

Order indet.

Suborder Paraparchitocopina Gramm, 1975

Superfamily Paraparchitacea Scott, 1959

Family Paraparchitidae Scott, 1959

Genus *Shishaella* Sohn, 1971

Shishaella cf. *williamsae* Sohn, 1971

(Pl. 7, fig. 3.)

Diagnosis. Carapace subcircular in lateral view. DM gently convex, VM broadly convex, ends almost equally rounded. Maximum height just anterior to mid-length. Dorsoposterior spine very close to the dorsal margin of the right valve. Surface smooth.

Material. 3 valves.

Occurrence. *S. williamsae* has been recorded from the Upper Mississippian (Lower Meramecian) of Alaska (Sohn, 1971).

Genus *Shivaella* Sohn, 1971

Shivaella armstrongiana (Jones & Kirkby, 1886)

(Pl. 7, fig. 4.)

1886 *Leperditia armstrongiana* - Jones & Kirkby, p. 253, Pl. 7, fig. 1

1932 *Paraparchites armstrongianus* - Latham, p. 356, fig. 4.

1971 *Shivaella armstrongiana* - Sohn, p. 8-9.

Diagnosis. Carapace subovate in lateral view, DM straight, VM convex, ends broadly rounded. Posterodorsal spine, surface smooth.

Material. 1 left valve.

Remarks. The lateral outline of the only specimen is slightly obscured by compaction in the sediment, a circular stump indicates the position of the posterodorsal spine.

Occurrence. Courcayan to Arnsbergian of Great Britain. It may be conspecific with *Shivaella* cf. *armstrongiana* from the late Dinantian of Belgium (Bless et al., 1981, p. 146, Pl. 1, figs. 5-8), *S. quasiporrecta* (Bushmina, 1968) from the Tournaisian of U.S.S.R., and *S. buccera* (Kummerow, 1953) from the Dinantian of Poland.

Order indet.

Superfamily Quasillitacea Coryell & Malkin, 1936

Family Quasillitidae Coryell & Malkin, 1936

Genus ? *Eriella* Stewart & Hendrix, 1945

?*Eriella minima* sp. nov.

(Pl. 3, figs. 6a,b)

Derivation of name. Latin, referring to the relatively small size (compared to that of other species of *Eriella*).

Explanation of Plate 9

Figs. 1-4 *Bairdiolites elevatus* Robinson 1959.

Fig. 1 RGM 350. 615, 25 cm, RV, L 0.90 mm, H 0.45 mm (x 70)

Fig. 2 RGM 350. 616, 25 cm, RV, L 1.05 mm, H 0.53 mm (x 70)

Fig. 3 RGM 350. 617, 25 cm, dorsal view, L 0.95 mm, H 0.50 mm (x 70)

Fig. 4 RGM 350.618, 25 cm, RV, L 0.95 mm, H 0.51 mm (x 70)

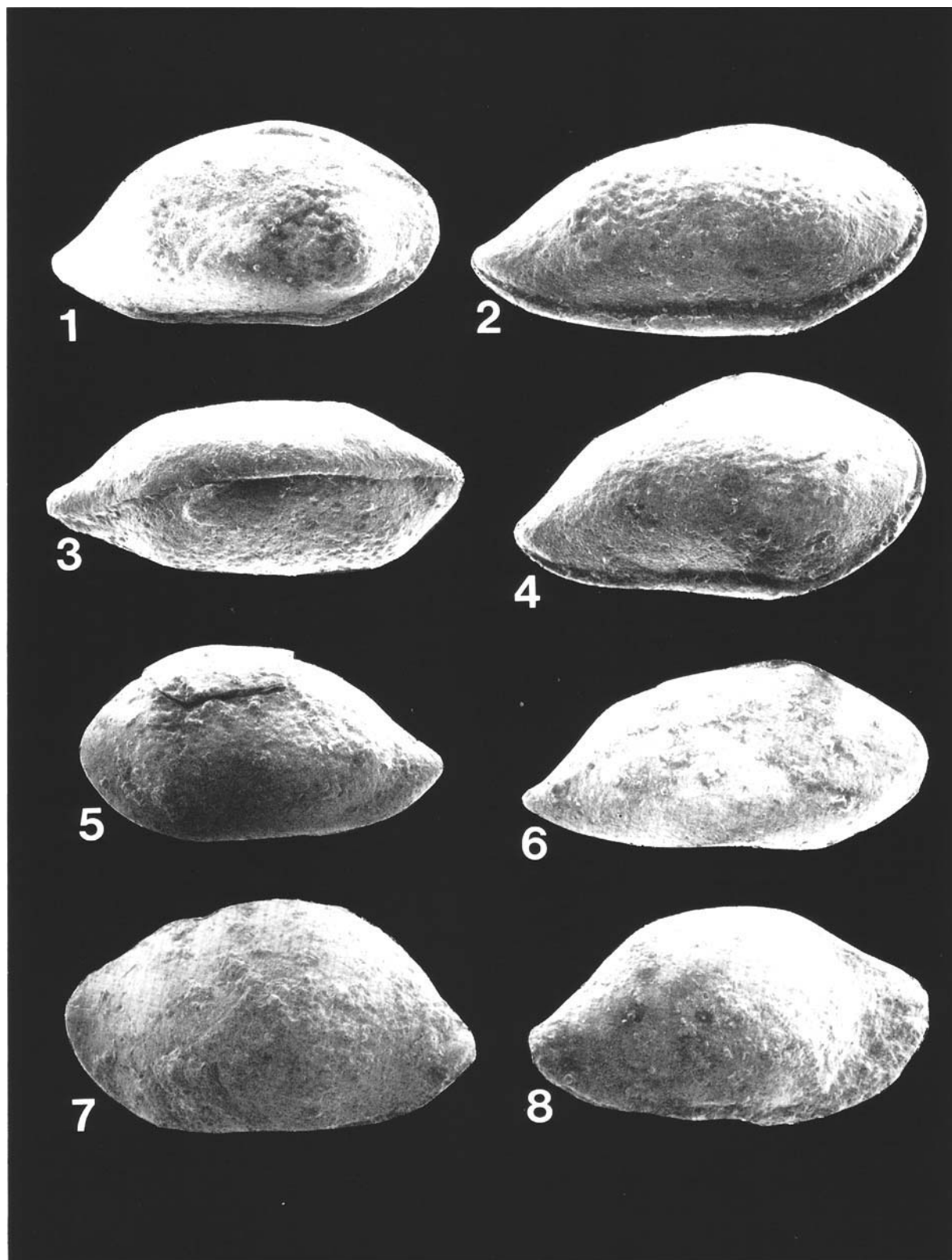
Fig. 5 *Bairdia beedei* Ulrich & Bassler, 1906, RGM 350.608, 870 cm, L 1.01 mm, H 0.52 mm, LV (x 60).

Fig. 6 *Bairdiolites elevatus* Robinson 1959 RGM 350. 619, 25 cm, RV, L 0.82 mm, H 0.39 mm (x 80).

Figs. 7-8 *Bairdia Harltoni* Cooper, 1941.

Fig. 7 RGM 350.611, 895 cm, LV, L 1.41 mm, H 0.76 mm (x 55)

Fig. 8 RGM 350. 612, 920 cm, RV, L 1.25 mm, H 0.51 mm (x 60)



Diagnosis. Carapace oblong, DM straight, hinge line straight and channelled. DM and VM subparallel, ends rounded. LV larger, overlapping RV along the entire margin. Surface regularly reticulated with a central smooth muscle spot.

Holotype. RGM 350. 635

Paratype. RGM 350. 636

Material. 2 carapaces.

Remarks. The species shows similarities in surface ornament to *E. ? cribraria* Green, 1963 from the Lower Carboniferous Banff Formation, Alberta (Green, 1963, Pl. 14, figs. 9-20). It differs from the type species of *Eriella* (*E. robusta* Stewart & Hendrix, 1945) in the absence of a distinct antero-marginal flange. The generic assignment on this criterion is therefore doubtful (Bless & Massa, 1982). However, the occurrence of another species with strong affinities to *Eriella* and lacking distinct marginal flanges, *E. ? courceyana* (Robinson, 1978, Pl. 10, figs. 6a,b), implies that the development of the antero-marginal flange may be of minor diagnostic importance, as already assumed by Robinson (1978).

Order Platycopida Sars, 1866

Suborder Platycopina Sars, 1866

Superfamily Cytherellacea Sars, 1866

Family Cavellinidae Egorov, 1950

Genus *Cavellina* Coryell, 1928

Cavellina cf. *benniei* (Jones, Kirkby & Brady, 1884)

(Pl. 8, fig. 1)

Diagnosis. Carapace elongate-quadrate in lateral view. DM and VM almost straight and subparallel, dorsum incurved. Valves compressed anteriorly and swollen posteriorly. Anterior end rounded, posterior end almost straight. Central muscle spot just above mid-length. RV larger, overlap most prominent along the anterior margin. Surface smooth.

Material. 1 carapace.

Remarks. *C. benniei* shows a considerable variation in size and shape (Jones, Kirkby & Brady, 1884), a study of which might lead to subdivision.

Occurrence. Robinson (1978, p. 132, Pl. 2, fig. 1) described *C. benniei*, ranging from the uppermost Brigantian to Arnsbergian of Great Britain.

?Class Ostracoda Latreille, 1806

Genus *Cryptophyllus* Levinson, 1951

Cryptophyllus sp.

(Pl. 8, fig. 2.)

Diagnosis. Carapace umbonate, greatest width at about mid-height, greatest length ventral. Hinge line short, depressed below the dorsal order. Ventral, anterior and posterior borders rounded, ventral broader. Antero- and posterodorsal borders straight or slightly concave.

Material. 9 carapaces, generally poorly preserved.

Remarks. A variable number of delicate concentric ridges (7 or more) is detected on the surface of some of the specimens examined.

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