Brachiopods and their response to the Early–Middle Frasnian biogeochemical perturbations on the South Polish carbonate shelf

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The brachiopod faunas from deposits recording the Early–Middle Frasnian transition of Poland are poorly known. The present report describes these faunas that were recovered from Wietrznia and Kostomłoty (Holy Cross Mountains) and Dębnik (Silesian-Cracow Upland) regions positioned on the southern Polish carbonate shelf. The brachiopod distribution was analysed relative to a significant $\delta^{13}C$ excursion, referred recently to as *Palmatolepis punctata* Event. The sporadic occurrence of brachiopods at Dębnik makes it difficult to analyse the biotic response to this geochemical anomaly. However, higher brachiopod frequency in the topmost part of the section coincides with a gradual decrease of $\delta^{13}C$ down to the Frasnian background values. At two studied sections at Wietrznia the greatest taxonomic diversity and abundance of brachiopods (*Flabellulirostrum–Coeloterorhynchus* assemblage) are confined to the *Palmatolepis transitans* Zone. In the following *Pa. punctata* Zone brachiopods are rare (*Biernatella lentiformis* assemblage) or absent, which suggests a serious deterioration of the environmental conditions linked probably with periods of benthic anoxia-dysoxia and oligotrophic conditions in the basin. In two Kostomłoty sections brachiopods faunas of this age are members of the mostly monospecific rhynchonellid-dominated *Phlogoiderhynchus polonicus* assemblage which inhabited deeper-water environments characteristic of intrashelf oxygen-depleted basins of Łysogóry-Kostomłoty region. In some horizons large shells of *P. polonicus* were frequently colonised by discinoid *Romerella*? sp. Among 28 species described in this report new forms include: *Flabellulirostrum kielcensis* sp. nov., *F. rackii* sp. nov., and *Thomasaria ventosa* sp. nov.

Key words: Brachiopoda, *Flabellulirostrum*, *Thomasaria*, carbon isotopes, diversity dynamic, Frasnian, Poland.

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Introduction

This study is a contribution to the interdisciplinary project initiated by Grzegorz Racki (Faculty of Earth Sciences, University of Silesia, and Institute of Paleobiology, Polish Academy of Sciences, Poland) to investigate the Early to Middle Frasnian biotic succession and events revealed in carbonate sequence of the part of the Laurussian shelf in southern Poland. It is noteworthy that this interval, which is correlated with *Palmatolepis transitans–Pa. punctata* conodont zones, has been recognised in recent literature as time of a major global transgressive, anoxic and geochemical events (e.g., McGhee 2001; House 2002; Schieber 2003; Yans et al. in press). Recently published high-resolution carbon isotopic data from Ardennes and Poland (Racki et al. 2004; Pisarzowska et al. 2006; Yans et al. in press), and other data from China (Bai et al. 1994) and Moravia (Hladikova et al. 1997) show a global negative carbon isotope shift in the *Pa. punctata* conodont Zone. According to Yans et al. (in press) these data document a worldwide perturbation in the earth–ocean system. As potential causes of this rapid (estimated roughly at 0.1 My) changes in the carbon isotopic composition of the oceanic reservoir the latter authors consider the Alamo Impact Event (Nevada, USA), massive dissociation of methane hydrate, and global warming (Yans et al. in press). The present paper deals with brachiopod faunas and their distribution patterns in the Early to Middle Frasnian (*Pa. transitans* to *Pa. punctata* conodnt zonal interval) from several outcrops in the Holy Cross Mountains (Wietrznia I, Kostomłoty II and V) and Silesian-Cracow Upland, southern Poland (Dębnik). This study contributes to the knowledge of the faunal response and palaeoecologic impact of the "*punctata* Event" (= *Pa. punctata* Event; as defined by Yans et al. in press) on brachiopod faunas in southern Poland.

Institutional abbreviations.—GIUS, Department of Paleontology and Biostratigraphy of the University of Silesia, Sosnowiec, Poland; ZPAL, Institute of Paleobiology, Polish Academy of Sciences, Warsaw, Poland.

Geological setting

Exposures of the Early–Middle Frasnian deposits of the Holy Cross Mountains and the Cracow region have been studied since the 19th century (see overview in Szulczewski 1971).

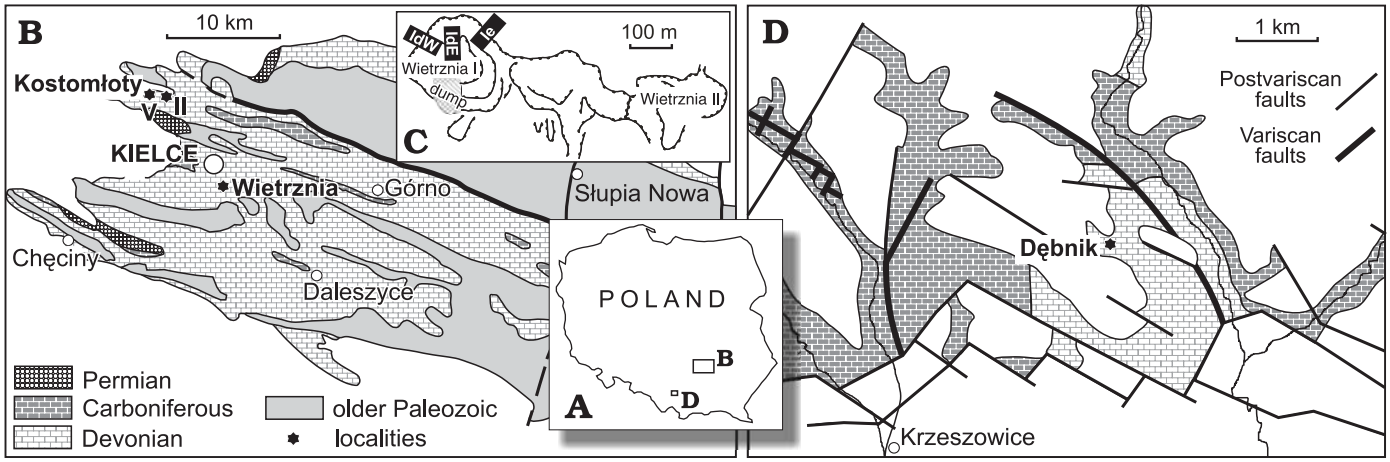

Fig. 1. Location of collecting sites. **A**. General map of Poland. **B**. Geological sketch-map of the western part of the Holy Cross Mountains (after Racki et al. 2004; modified). **C**. Sketch map of Wietrznia quarries and location of the studied sections (after Makowski in Racki et al. 1993, simplified). **D**. Geological sketch-map of the Dębnik vicinity (after Szulczewski and Dvořák 1995; modified).

The exposed strata form an elongate belt between the south-western margin of the East European Craton and Variscan Deformation Front (Dadlez et al. 1994). They were deposited in the proximal part of an intracratonic basin up to 600 km in width, trending NW–NE, that extend from Western Europe to the Ukraine (Narkiewicz 1985). Among exposures of the Early–Middle Frasnian passage beds the Wietrznia Id-W and Ie sections were analysed in detail (Figs. 1–3). These sections represent a continuous sedimentary succession which includes a record of global and regional geochemical and biotic events. For the purposes of the present study these sections in the Holy Cross Mountains were sampled in detail to obtain high-resolution data on the conodont sequence (Pisarzowska et al. 2006) as well as the Frasnian brachiopod fauna. Supplementary brachiopod material was collected from Kostomłoty Małe Górki (= Kostomłoty II; see Racki et al. 2004: 269, figs. 2–4, 8) and Kostomłoty-Mogiłki (Kostomłoty V; see Racki et al. 2004: 269, figs. 2, 8) quarries (Holy Cross Mountains) as well as from Dębnik (Silesia-Cracow Upland, southern Poland; see Baliński 1979: fig. 1).

The Wietrznia I inactive quarry is situated in the southern part of Kielce, within the southern limb of Kielce Syncline (Szulczewski 1971: 69, fig. 7; Fig. 1 herein). Five lithostratigraphic sets (A through E) of the latest Givetian–Frasnian limestones that crop out in the area have been described earlier by Szulczewski (1971). The brachiopod fauna described in this report comes from set C which represents the middle part of the Wietrznia Beds (= *Phlogoiderhynchus* Marly Level of Racki 1993a). At the Wietrznia Id-W section the set consists of about 8 m of thin-bedded bituminous micrites and interbedded marly shales or calcirudites (see details in Makowski in Racki et al. 1993: 81, figs. 9–10; Pisarzowska et al. 2006). Thin-bedded bituminous micrites with many fossiliferous coarse-grained and graded biointrarudite intercalations are characteristic for nearby Wietrznia Id-E section, where the set C is nearly 9.5 m in thickness (Pisarzowska et al. 2006). At Wietrznia Ie section, set C is incompletely exposed (without its basal 1.5 m part) and is ca. 7 m in thickness. The succession is composed mainly of rhythmically bedded, platy bituminous calcilutites and marly shales, with occasional thin calcirudites and biorudites (for more details see Makowski in Racki et al. 1993: 81, figs. 9–10; Pisarzowska et al. 2006).

A few specimens of *Roemerella*? sp. and *Phlogoiderhynchus polonicus* (Roemer, 1866) were found at Kostomłoty V located ca. 3 km NNE of Kielce from exposures of dark micrites with shaly and detrital intercalations. These strata represent the middle part of the Szydłówek Beds (Racki and Bultynck 1993). Abundant collections of the same two species mentioned above were recovered from Kostomłoty II quarry where the same interval is well exposed (for more details on the outcrops see Racki et al. 2004).

A small brachiopod collection was recovered from a quarry north of the village of Dębnik (= quarry above the Rokiczany Dół ravine in Baliński 1979; Silesia-Cracow Upland, southern Poland). Rocks in the Dębnik area represent the southern facies of the pericratonic basin located near the stable, elevated Sub-Carpathian Arch (Narkiewicz 1985, 1988). Brachiopods recovered from this area were collected in the western part of the quarry where the youngest layers have been recently exposed. This section yields faunas of two local brachiopod zones: the older *Cyrtospirifer bisellatus* Zone, and the lowermost part of the succeeding *Plionoptycherhynchus cracoviensis* Zone. The rocks yielding these faunas consist of a monotonous succession of interbeded thin marly micrites and marls, sparse calcirudites, and intraclastic limestones (Nodular Limestone unit of Narkiewicz and Racki 1984). It is noteworthy that the topmost layers of the section with assemblages of the *Plionoptycherhynchus cracoviensis* brachiopod zone are the only known *in situ* occurrence of faunas of the interval. Previously, it was known exclusively from loose blocks found at the bottom of the nearby Rokiczany Dół ravine (Baliński 1979).

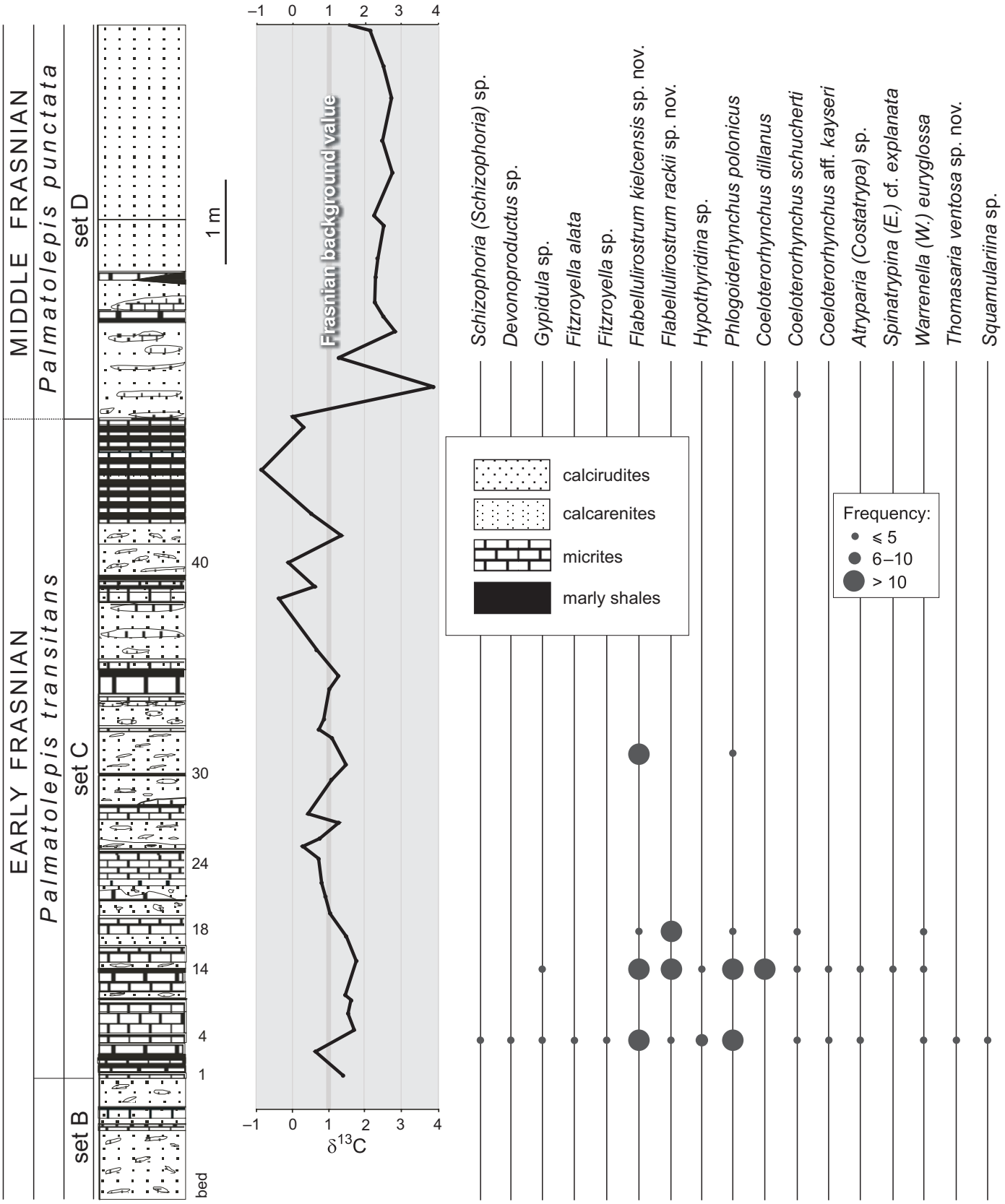

Fig. 2. Distribution of brachiopod species in Wietrznia Id-W section. Lithology, stratigraphy, and stable carbon isotope geochemistry after Pisarzowska et al. (2006).

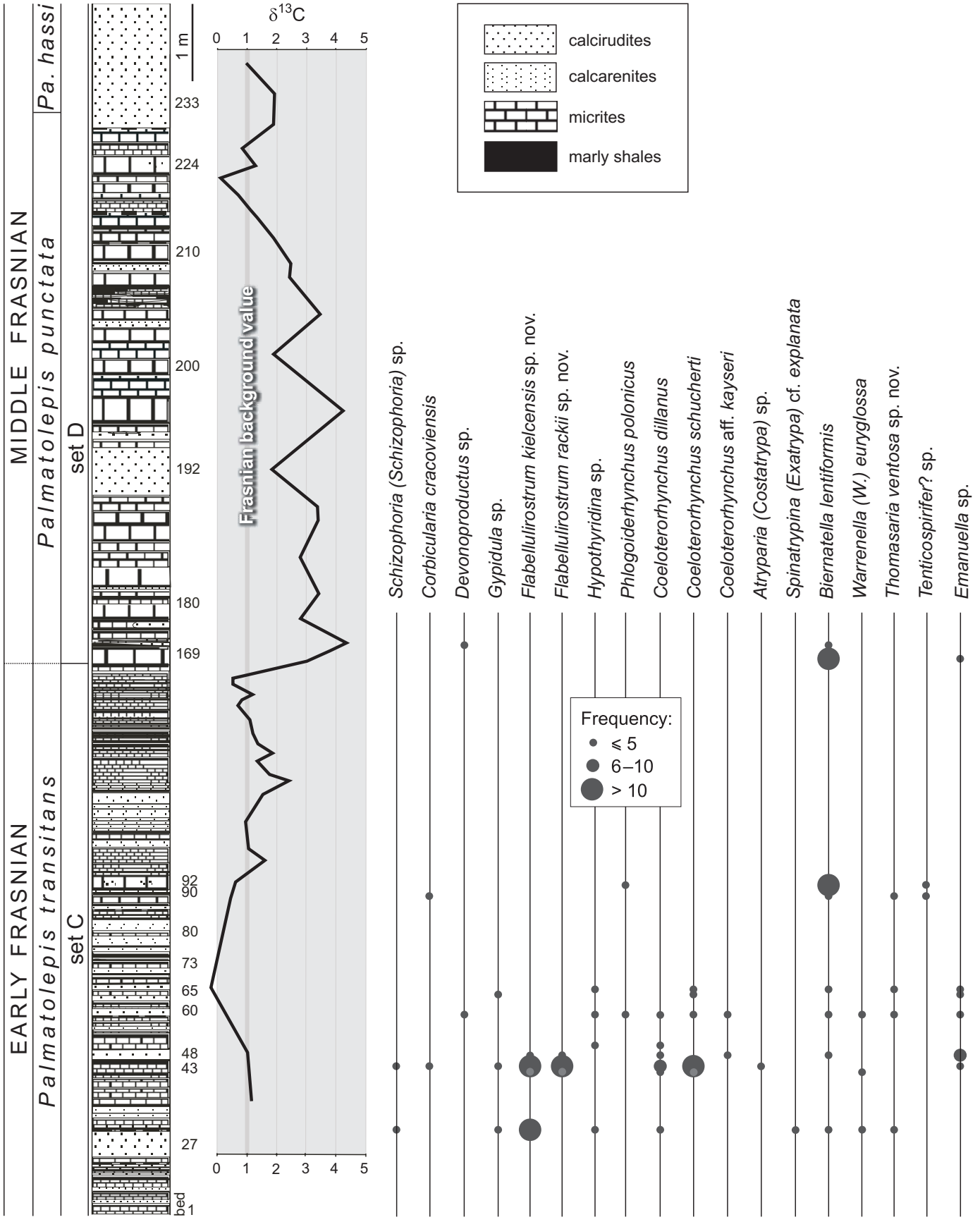

Fig. 3. Distribution of brachiopod species in Wietrznia Ie section. Lithology, stratigraphy, and stable carbon isotope geochemistry after Pisarzowska et al. (2006). Abbreviation: *Pa.*, *Palmatolepis*.

Diversity dynamic of brachiopod faunas

As noted above, the brachiopod faunas studied here come from three localities representing different palaeogeographic and sedimentological settings. These are, from the south to north: Dębnik, Wietrznia (Id-W and Ie), and Kostomłoty (II and V).

Dębnik.—The latest Givetian sequence in the area is marked by elimination of coral-stromoatoporoid biostromes and increase in clay content and evidence for dysaerobic conditions with short episodes of improved water circulation. The latter are indicated by the appearance of monospecific accumulations of atrypid shells (Racki and Baliński 1981). The transgression continued in the earliest Frasnian as indicated by the appearance of more diversified brachiopod fauna (Baliński 1979, 1995a). Noteworthy is the first occurrence of *Cyrtospirifer* in this interval represented by endemic *C. bisellatus* (Gürich, 1903) and a total absence of rhynchonellids. Other elements of this fauna described earlier by Baliński (1979) include *Corbicularia cracoviensis* Baliński, 1979, *Douvillina* sp., *Spinatrypa semilukiana* Ljaschenko, 1951, *Devonatrypa velikaja* Nalivkin, 1941, and *Eleutherokomma zarecznyi* (Gürich, 1903). This brachiopod fauna represents the *Cyrtospirifer bisellatus* assemblage as proposed here (Fig. 4).

The first rhynchonellids of the *Plionoptycherhynchus cracoviensis* assemblage, described herein, appear in the topmost layers of the section, representing the base of the *Plionoptycherhynchus cracoviensis* Zone. The brachiopod fauna is more diverse and abundant in this interval than in the underlying *Cyrtospirifer bessilatus* Zone. Characteristic species of the *Plionoptycherhynchus cracoviensis* assemblage (Fig. 4) are the nominal species *P. cracoviensis* (Gürich, 1903) and *C. bisellatus* (dominant species), with *Douvillina* sp., *Flabellulirostrum guerichi* (Baliński, 1979), and *Thomasaria* sp.

The $\delta^{13}C$ carbon isotope record through the Early–Middle Frasnian transition interval in the Dębnik section (see details in Pisarzowska et al. 2006) shows a major positive excursion of nearly 4‰ in the uppermost *Pa. transitans*–lowermost *Pa. punctata* zones, followed by highstand during most of the latter zone, displaying a final gradual decrease in $\delta^{13}C$ values in the uppermost part of the section. The sporadic frequency of brachiopod assemblages in the section makes it difficult to analyse the biotic response to this geochemical anomaly. Overall there is no documented evidence of any major faunal perturbation in the interval recording the *punctata* Event $\delta^{13}C$ excursion. Of note here is an increase in brachiopod frequency that records a gradual decrease of $\delta^{13}C$ values and return to the Frasnian background values (Pisarzowska et al. 2006).

Wietrznia.—The brachiopod fauna (atrypoids and hypothyridinids) from Kadzielnia and possibly Wietrznia were mentioned by Czarnocki (1948: 243). More recent but largely unpbublished studies of the brachiopods from Wietrznia include Makowski (1988), Makowski in Racki et al. (1993), and Budziszewska (1990). Described forms from Wietrznia include the pentamerid *Novozemelia*? sp. W (Godefroid and Racki 1990), and the rhynchonellid *Phlogoiderhynchus polonicus* (Roemer, 1866) in a study by Biernat and Szulczewski (1975).

The brachiopod fauna here described was recovered in samples from two sections in the Wietrznia quarry, namely Id-W and Ie (Figs. 1–3). In both sections the frequency of brachiopods is much higher in the lower part of the set C, and are lower in its upper part. In the overlaying set D brachiopods are very rare or absent (Figs. 2, 3). Brachiopods are most numerous and diverse in beds 4 and 14 of Id-W section and beds 43–44 and 60 of Ie section. Samples from those beds are rhynchonellid-dominated and assigned here to the *Flabellulirostrum–Coeloterorhynchus* assemblage. Characteristic species of the *Flabellulirostrum–Coeloterorhynchus* assemblage include *Flabellulirostrum kielcensis* sp. nov., *F. rackii* sp. nov., *Coeloterorhynchus dillanus* (Schmidt, 1941), *C. schucherti* (Stainbrook, 1945), and in addition *Phlogoiderhynchus polonicus* (Roemer, 1866) in the Id-W section. These rhynchonellid species markedly outnumber the rest of the fauna of the assemblage (Figs. 2, 3).

Most of brachiopods of the assemblage were attached by a pedicle to hard objects although in some species it may have functioned only in early growth stages. It is possible that some mature individuals of *Flabellulirostrum*, *Coeloterorhynchus*, and *Phlogoiderhynchus* lost their pedicle and were liberosessile (freelying) on the substrate as adults. This interpretation is supported by the fact that the ventral beak is strongly incurved and pressed against the brachial valve leaving little or no room for a functional pedicle in large adult specimens of those genera. The thick shell material in the umbonal region of these shells and strongly uniplicate anterior commissure may have aided in holding them in suitable orientation (see illustrated growth position in Makowski in Racki et al. 1993: 86, pl. 17: 2–4).

The character of the sediment suggests, however, that in environment occupied by this assemblage suitable attachment sites have been very limited, consisting apparently of other brachiopod shells. This may well explains the gregarious clusters of brachiopods characterising the distribution of specimens in these beds (see Makowski in Racki et al. 1993: 86, fig. 13).

The youngest brachiopod fauna in the studied interval was recovered in the middle part of *Pa. transitans* Zone (bed 90 and 92) and basal part of the *Pa. punctata* Zone (bed 169 and 171) in the Wietrznia Ie section (Fig. 3). This is low-diversity fauna dominated by small shells of the athyridoid *Biernatella lentiformis* Baliński, 1995b. Other brachiopods of the assemblage include rare and fragmentary specimens of *Devonoproductus* sp., *Corbicularia cracoviensis* Baliński, 1979, *Phlogoiderhynchus polonicus* (Roemer, 1866), *Emanuella* sp., *Tenticospirifer* sp., and *Thomasaria ventosa* sp. nov. The state of preservation of the brachiopods suggest that this impoverished epifauna lived in environment characterised by high hydrodynamic activity and probably undergone some sort of transport prior to burial in sediment. This fauna comprises the *Biernatella lentiformis* assemblage (Fig. 4).

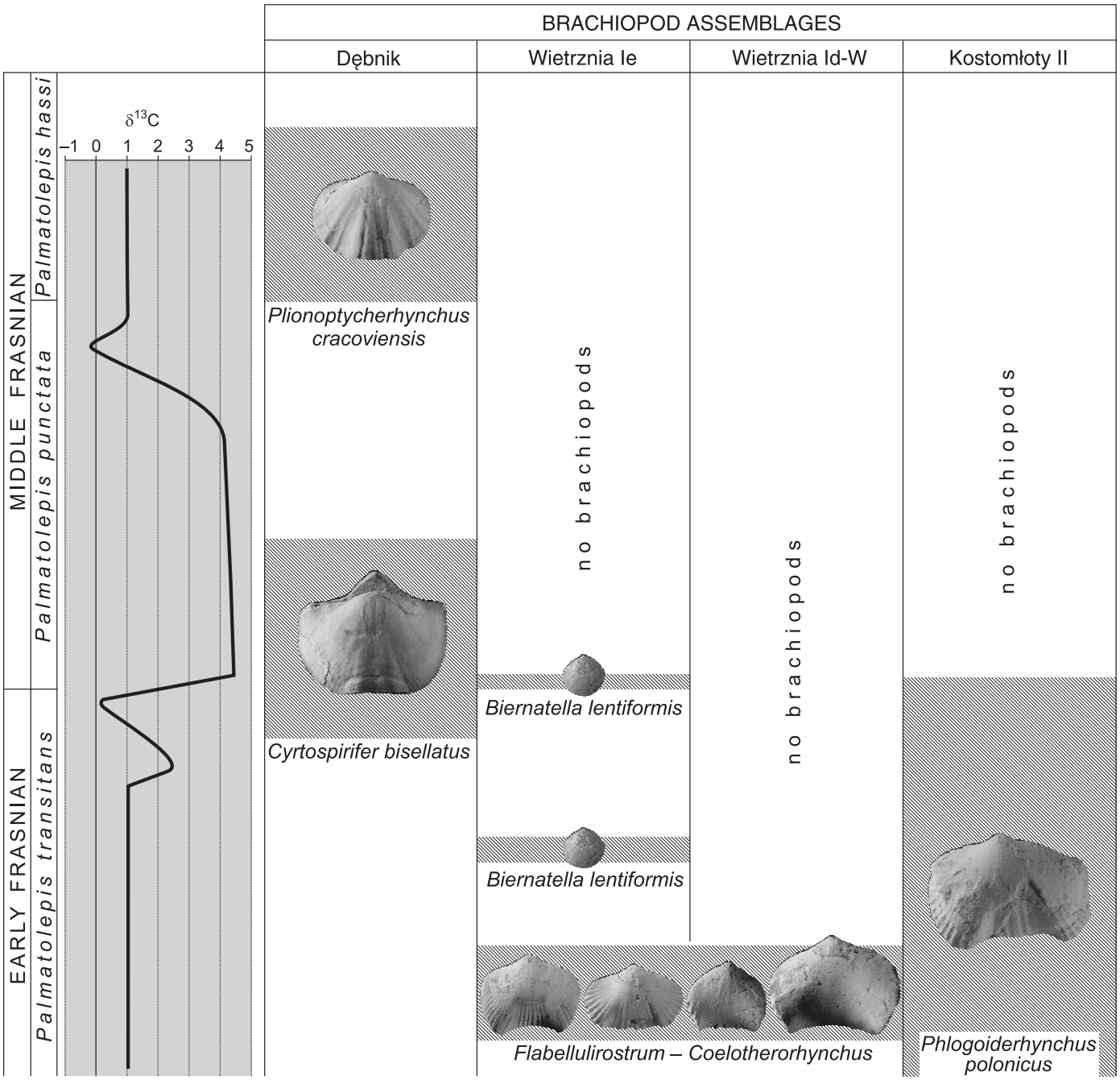

Fig. 4. Succession of brachiopod assemblages in studied sections during the Early–Middle Frasnian (*Palmatolepis transitans–Pa. hassi* conodont zones) against carbon isotope record; the $\delta^{13}C$ curve generalised from detailed records of Pisarzowska et al. (2006). Abbreviation: *Pa.*, *Palmatolepis*.

The $\delta^{13}C$ carbon isotope record at both the Ie and Id-W sections at the Wietrznia quarry shows a major positive excursion of ca. 4‰ amplitude in the *Palmatolepis punctata* Zone whereas during the most of *Pa. transitans* Zone the $\delta^{13}C$ curve oscillates near the Frasnian background values (see details in Pisarzowska et al. 2006; Figs. 2–4). The greatest taxonomic diversity and abundance of brachiopods in these sections are confined to the interval of the *Pa. transitans* Zone. From the succeeding *Pa. punctata* Zone brachiopods are not known except the earliest part of the interval where they occur as extensively reworked shelly material (*Biernatella lentiformis* assemblage, Fig. 4). Thus, it can be assumed that during the *punctata* Event (see Pisarzowska et al. 2006; Yans et al. in press) the environmental conditions for brachiopod faunas have deteriorated and rhynchonellid dominated assemblage vanished from the area. A similar distribution pattern is seen in the crinoid and ostracod faunas from the sections by Głuchowski et al. (2006). The observed impoverishment of the fauna may be explained by the significant global sea level rise and associated transgressive pulse

in the *Palmatolepis punctata* Zone (Middlesex Event; see House 2002) and development of oxygen- and nutrient-deficient condition in the basin. This may be linked with development of vascular land plants which likely expanded their ranges into the vast flood-plain areas at that time. The importance of evolutionary developments of vascular land plants is difficult to overemphasise because it may have been the ultimate cause for oceanic anoxic events, biotic crises, global climate change, and geochemical and sedimentologic anomalies (Algeo et al. 1995).

Kostomłoty.—The brachiopod material reported here from Kostomłoty was collected in two quarries (Kostomłoty II and V). At these localities the Early Frasnian part of the section (middle part of the Szydłówek Beds, see Racki and Bultynck 1993; Racki et al. 2004; Sartenaer and Racki 1992), consists of deeper-water facies characteristic of intrashelf oxygen-depleted basins of the Łysogóry-Kostomłoty region. Faunal, geochemical, and palaeoenvironmental analysis of the Szydłówek Beds were conducted by Racki et al. (2004).

The recovered brachiopods which inhabited a muddy sea bottom were assigned to the almost monospecific rhynchonellid-dominated *Phlogoiderhynchus polonicus* assemblage of Racki (1993). This assemblage also includes extremely rare atrypids and lingulids (Biernat and Szulczewski 1975: 213). A small morphotype of *P. polonicus* was reported by Sartenaer and Racki (1992) from the upper member of the Szydłówek Beds. During the present investigation another important member of the assemblage was recovered in some horizons, i.e., inarticulate *Romerella*? sp. This epibiont brachiopod frequently colonised large shells of *P. polonicus* (Fig. 5) that served as a rare hard substrate suitable for attachment site for *Romerella*? sp. on the muddy sea floor in the Kostomłoty area. This highly impoverished brachiopod fauna of the Szydłówek Beds suggests that some environmental factor must have severely limited the development of the shelly benthos. Biernat and Szulczewski (1975) concluded that *Phlogoiderhynchus polonicus* occurs in sediments of an open-sea environment with normal salinity, relatively deep-water, below the storm wave-base. The paucity of brachiopods in *P. polonicus* assemblage is probably due to oxygen-depleted (dysoxic) conditions and high mud accumulations rates. Only *P. polonicus* and, in some horizons, discinoid *Romerella*? sp. seem to have been well adapted to this kind of environment (see Rhynchonellid Biofacies of Racki et al. 1993: 89). According to Racki (1993b) and Sartenaer and Racki (1992) *P. polonicus* expanded its geographic range southwardly from northern (Łysogóry-Kostomłoty) region to the northern and then southern Kielce region. Similar southward expansion is observed in *Flabellulirostrum*, which is very common in *Pa. transitans* Zone in the Holy Cross Mountains (Wietrznia), whereas in the Dębnik area the genus appears as late as *Pa. hassi* Zone.

Systematic palaeontology

General remarks.—The brachiopod material studied here contains about 450 specimens, which were collected in Wietrznia I quarry (sections Id-W and Ie) and 52 specimens collected from northern quarry at village of Dębnik near Krzeszowice, S Poland. Part of the material comes from the collections housed at Silesian University where they are kept as documentation of master theses of Ewa Budziszewska (1990) and Ireneusz Makowski (1988). In addition, collection described earlier from the Dębnik anticline by the author (Baliński 1979) was also used. One rhynchonellid *Phlogoiderhynchus polonicus* and one discinoid *Romerella*? sp. from Kostomłoty have been also included in this report.

Order Lingulida Waagen, 1885
Superfamily Discinoidea Gray, 1840
Family Trematidae Schuchert, 1893
Genus *Roemerella* Hall and Clarke, 1890

Type species: *Orbicula grandis* Vanuxem, 1842; Hamilton Group, Devonian, USA.

Roemerella? sp.

Fig. 5.

Material.—Thirty four strongly flattened and crushed specimens from Kostomłoty II (= Małe Górki) and one specimen from Kostomłoty V (= Kostomłoty Mogiłki).

Remarks.—This species has been included in this report despite its occurrence in a slightly distant locality (ca. 10 km NW of Wietrznia) because of its faunistic importance. It was revealed in the late Givetian–early Frasnian boundary interval represented by middle Szydłówek Beds which are characterised by interlayering of marly shales and marly limestones (e.g., Satenaer and Racki 1992; Racki at al. 2004).

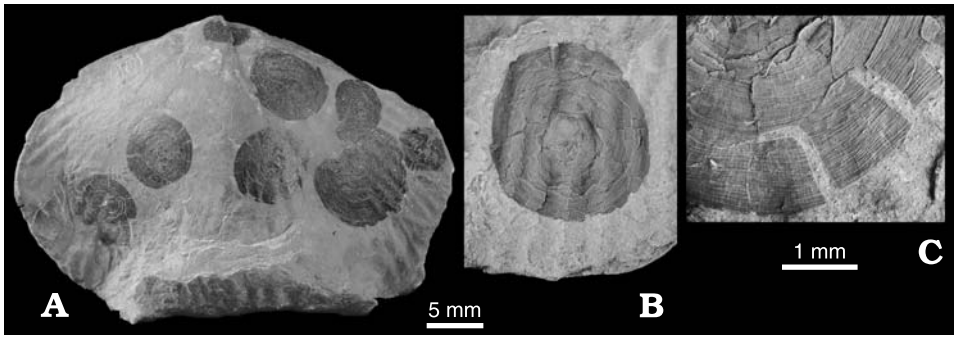

Fig. 5. Discinoid *Roemerella*? sp. from middle Szydłówek Beds, Kostomłoty II. **A**. ZPAL Bp 60/27-10, nine specimens adhered to large shell of *Phlogoiderhynchus polonicus* (Roemer, 1866). **B**. ZPAL Bp 60/27-9, strongly flattened specimen adhered in the sulcus of a shell of *Phlogoiderhynchus polonicus*. **C**. ZPAL Bp 60/27-6, enlargement of flattened and crushed specimen showing details of surface ornamentation.

These sediments represent deeper basinal setting than that at Wietrznia I. The only articulated brachiopod revealed in this soft-bottom environment of the interval is large-shelled rhynchonelloid *Phlogoiderhynchus polonicus* (Roemer, 1866) (see description below; see also Biernat and Szulczewski 1975). It seems that these shells were frequently used as the only firm attachment site for *Roemerella*? sp. Out of 89 specimens of *P. polonicus* revealed at Kostomłoty II during the present study, 13 (i.e., 15%) bear *Roemerella*? sp. attached. Number of attached specimens on one shell of *P. polonicus* varies from 1 to 12 (Fig. 5).

All studied specimens are strongly flattened and crushed as a result of compaction of the marly shales in which the species occurs. The largest specimen, which preservation allows measurement, attains 9.7 mm in diameter. In most cases only dorsal valve is visible because ventral one is concealed underneath resting on the surface of the host shell. The surface of the dorsal valve is ornamented by dense microscopic growth lines and very dense radial striae (24–40 per 1 mm; Fig. 5C). Externally, the studied specimens are like *Roemerella* but lack of details on the interior of the ventral valve makes the generic identification somewhat tentative.

Occurrence.—The species is quite common, occurring as epifauna on the shells of *Phlogoiderhynchus polonicus* (Roemer, 1866) from middle part of the Szydłówek Beds of Kostomłoty II quarry, and, much less frequently, in the same interval that crops out at Kostomłoty V quarry (both a few kilometres NNW of Kielce). This is the first record of the genus in Poland.

Order Orthida Schuchert and Cooper, 1932

Superfamily Enteletoidea Waagen, 1884

Family Schizophoriidae Schuchert and LeVene, 1929

Genus *Schizophoria* King, 1850

Subgenus *Schizophoria* (*Schizophoria*) King, 1850

Type species: *Conchyliolithus* (*Anomites*) *resupinatus* Martin, 1809; Carboniferous, Great Britain.

Schizophoria (*Schizophoria*) sp.

Fig. 6A.

Material.—Three very fragmentary specimens were found in beds 29, 48 (Wietrznia Ie), and 4g (Wietrznia Id-W).

Remarks.—The poor state of preservation of the present specimens does not permit satisfactory comparison with any species of the genus.

Occurrence.—This is very rare species in Wietrznia Id-W and Ie sections (*Palmatolepis transitans* Zone).

Order Strophomenida Öpik, 1934

Superfamily Strophomenoidea King, 1846

Family Duvillinidae Caster, 1939

Subfamily Duvillininae Caster, 1939

Genus *Douvillina* Oehlert, 1887

Type species: *Orthis dutertrei* Murchison, 1840; Frasnian, France.

Douvillina sp.

Fig. 6E.

1979 *Douvillina* (*Douvillina*) sp.; Baliński 1979: 28, pl. 2: 1, 2.

Material.—Four fragmentary and partly exfoliated specimens embedded in rock in addition to 60 other, mostly fragmentary specimens from the older collection (see Baliński 1979).

Remarks.—This form was described and compared to other species by Baliński (1979).

Occurrence.—The present collection comes from the topmost layers of the west wall of the northern quarry near village of Dębnik. Previously the species was recovered from loose blocks found near the quarry and in the upper part of Rokiczany Dół ravine (*Cyrtospirifer bisellatus* and *Plionoptycherhynchus cracoviensis* local brachiopod zones; Baliński 1979).

Order Productida Sarytcheva and Sokolskaya, 1959

Suborder Chonetidina Muir-Wood, 1955

Superfamily Chonetoidea Bronn, 1862

Family Chonetidae Bronn, 1862

Subfamily Dagnachonetinae Racheboeuf, 1981

Genus *Corbicularia* Ljashenko, 1973

Type species: *Chonetes menneri* Ljashenko, 1973; Frasnian, Russia.

Corbicularia cracoviensis Baliński, 1979

Fig. 6B, C.

1979 *Corbicularia cracoviensis* sp. nov.; Baliński 1979: 30–31, pl. 2: 5–10, pl. 3: 8–9.

Material.—Two single valves embedded in rock from beds 48 and 90 of Wietrznia Ie section.

Remarks.—Despite very poor state of preservation of specimens from Wietrznia they can be quite confidently attributed to the species which was earlier described from the Early Frasnian of the Dębnik anticline (Baliński 1979).

Occurrence.—The species was described from the *Cyrtospirifer bisellatus* brachiopod Zone of the Dębnik anticline (Baliński 1979). Now recovered specimens come from Wietrznia Ie section.

Suborder Productidina Waagen, 1883

Superfamily Linoproductoidea Stehli, 1954

Family Monticuliferidae Muir-Wood and Cooper, 1960

Subfamily Devonoproductidae Muir-Wood and Cooper, 1960

Genus *Devonoproductus* Stainbrook, 1943

Type species: *Productella walcotti* Stainbrook, 1943; Frasnian, Iowa.

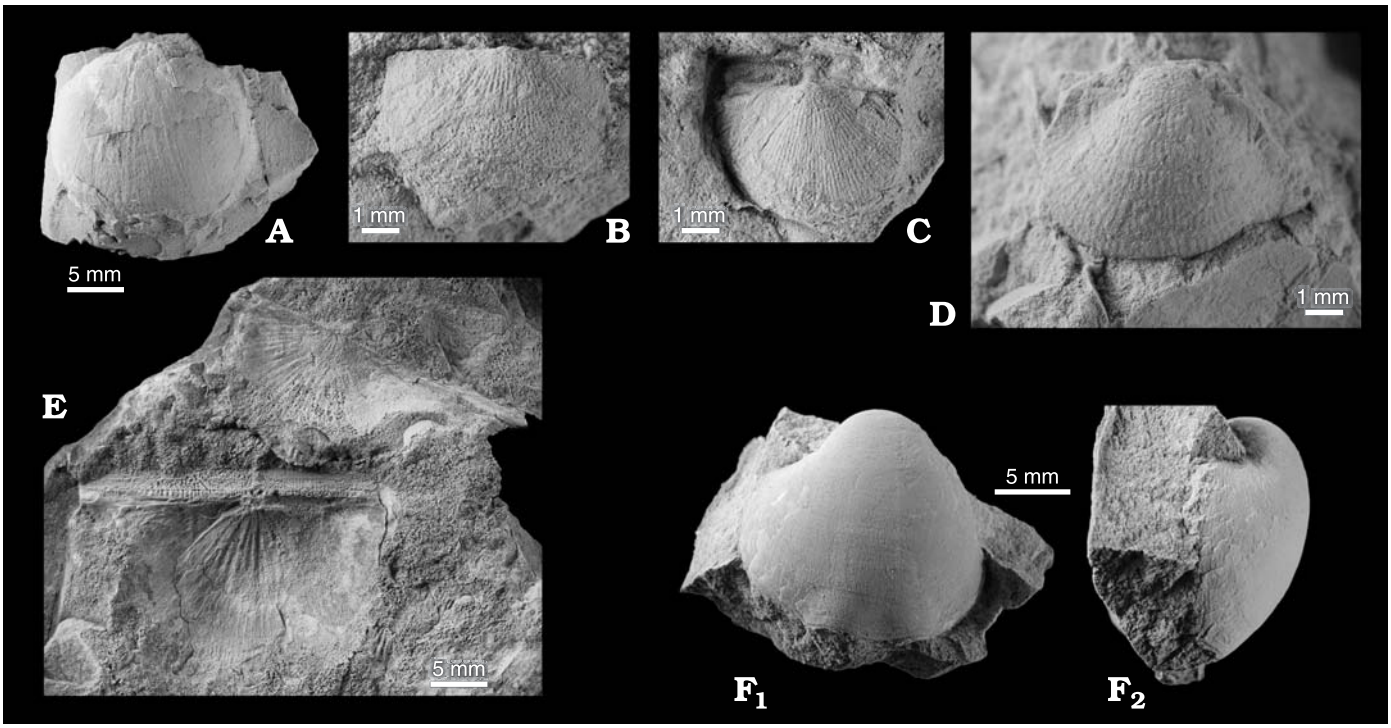

Fig. 6. Orthid, strphomenid, productid, and pentamerid brachiopods from the Frasnian of Wietrznia and Dębnik. **A**. *Schizophoria (Schizophoria)* sp., ZPAL Bp 60/1, exterior of dorsal valve from the middle Wietrznia Beds of Wietrznia Ie. **B**, **C**. *Corbicularia cracoviensis* Baliński, 1979, ZPAL Bp 60/18 (**B**) and ZPAL Bp 60/19 (**C**), two specimens embedded in rock from the Nodular Limestone (*Pa. hassi* Zone) of Dębnik. **D**. *Devonoproductus* sp., GIUS 4-273 Wt/IM-2, incomplete ventral valve from the middle Wietrznia Beds of Wietrznia Ie. **E**. *Douvillina* sp., ZPAL Bp 60/13, two shells embedded in rock from the Nodular Limestone (*Pa. hassi* Zone) of Dębnik. **F**. *Gypidula* sp., ZPAL Bp 60/23, ventral (F_1) and lateral (F_2) views of the ventral valve from the middle Wietrznia Beds of Wietrznia Ie.

Devonoproductus sp.

Fig. 6D.

Material.—Four very fragmentary single valves embedded in rock from bed 4 of Wietrznia Id-W section and beds 60 and 171 of Wietrznia Ie section.

Remarks.—Character of external shell ornamentation suggests that described specimens most probably represent a member of *Devonoproductus* Stainbrook, 1943.

Occurrence.—Extremely rare species in Wietrznia Id-W and Ie sections.

Order Pentamerida Schuchert and Cooper, 1931
Superfamily Gypiduloidea Schuchert and LeVene, 1929
Family Gypidulidae Schuchert and LeVene, 1929
Genus *Gypidula* Hall, 1867

Type species: *Gypidula typicalis* Amsden, 1953; Middle Devonian, Iowa.

Gypidula sp.

Fig. 6F.

Material.—Seven small fragments of disarticulated valves from Wietrznia Id-W (beds 4 and 14) and Ie (beds 29–30, 44–45, and 65) sections.

Remarks.—The described specimens can be attributed to the genus *Gypidula* on a basis of its very strongly convex ventral valve with a very massive umbo and characteristic short and thick radial plications which occur frequently in several species of the genus. Similar gypidulid was described by Godefroid and Racki (1990) as *Metabolipa* cf. *greindli* (Maillieux, 1909) from approximately the same age deposits of nearby Bolechowice, Kadzielnia and Szczukowskie Górki.

Occurrence.—Very rare species in Wietrznia Id-W and Wietrznia Ie.

Order Rhynchonellida Kuhn, 1949
Superfamily Uncinuloidea Rzhonsnitskaya, 1956
Family Uncinulidae Rzhonsnitskaya, 1956
Genus *Fitzroyella* Veevers, 1959

Type species: *Fitzroyella primula* Veevers, 1959; Frasnian, Fitzroy Basin, Australia.

Fitzroyella alata Biernat, 1969

Fig. 7C.

1969 *Fitzroyella alata* n. sp.; Biernat 1969: 377–386, pl. 1: 1–9, pl. 2: 1–4, pl. 3: 1–12, text-figs. 1–5.
1971 *Fitzroyella alata* Biernat, 1969; Biernat 1971: 144, pl. 2: 5.
1978 *Fitzroyella alata* Biernat, 1969; Struve 1978: 344–45, pl. 1: 1–5.
2003 *Fitzroyella alata* Biernat, 1969; Biernat in Baliński et al. 2003: 206, pl.155: 6, 7.

Material.—Three complete and two fragmentarily preserved

shells were recovered from set C of Wietrznia Id-W and Wietrznia II sections.

Remarks.—This is a very rare species in set C of Wietrznia sections. All three complete shells at hand are small attaining less than 6 mm in length. They show the same subpentagonal shell outline with alate hinge margin and strong radial ribbing as type specimens of *Fitzroyella alata* Biernat, 1969.

The recovery of *Fitzroyella* at Wietrznia is important as the genus seems to be rather rare in Poland. As for now only one species, i.e., *Fitzroyella alata* Biernat, 1969 was described from the Frasnian of Kowala and Kadzielnia (ca. 10 and 2 km from Wietrznia, respectively; see Biernat 1969). In Germany and Australia the genus was widely used for correlation of the Late Givetian–Frasnian deposits (Veevers 1959; Heinke 1978; Struve 1978; Sartenaer 1985; Brice 2000).

Occurrence.—The studied specimens were found in set C of the Wietrznia Id-W and II sections representing *Palmatolepis transitans* conodont Zone. Three specimens most probably representing the species were also recovered by G. Racki (personal communication 2005) from Early Frasnian deposits at Górno (ca. 12 km east of Wietrznia). Formerly, the species was described by Biernat (1969) from the Early Frasnian biostromal limestone of Kowala and Kadzielnia (Holy Cross Mountains).

Fitzroyella sp.

Fig. 7D, E.

Material.—One complete and two fragmentarily preserved shells were recovered from Wietrznia Id-W (bed 4 and loose debris) and Wietrznia II sections.

Remarks.—The specimens here described differ from those described above as *Fitzroyella alata* Biernat, 1969 being not as wide and by having non alate cardinal margin. The cardinal margin of the studied specimens is narrower the maximum width of the shell, and the shell is almost subquadrate in outline. Moreover, shell ribbing of these specimens seems to be not as strong as in *F. alata*. The specimens show some similarity in general shell form and ribbing to *Fitzroyella hartensis* Struve, 1978 and *Fitzroyella inversicor lapicidinae* Struve, 1978, both from the early part of the Frasnian of Germany (Struve 1978). Unfortunately, more precise identification of the species from Wietrznia is not possible at present due to inadequate studied material. On the other hand Biernat (1969: 385) emphasised great intraspecific variability in *F. alata* and remarked that in her collection occur specimens which could be considered as representatives of each known at that time species of *Fitzroyella*.

Occurrence.—The studied specimens were found in set C of the Wietrznia Id-W and Wietrznia II sections representing *Palmatolepis transitans* conodont Zone.

Genus *Flabellulirostrum* Sartenaer, 1971

Type species: *Uncinulus wolmericus* Veevers, 1959; Frasnian, Western Australia.

Flabellulirostrum kielcensis sp. nov.

Figs. 8B–D, 9, 10.

1988 *Flabellulirostrum* nov. sp. A; Makowski 1988: 33–36, pl. 13: 1–6, pl. 10: 1–5, text-fig. 13A.

1988 *Flabellulirostrum* nov. sp. B; Makowski 1988: 36–38, pl. 14: 2, 4, 6 (non 1, 3, 5 = *F. rackii* sp. nov.), pl. 12: 10, 11 6 (non 9, 12 = *F. rackii* sp. nov.), text-fig. 13B.

1993 *Flabellulirostrum* nov. sp. B; Makowski in Racki et al. 1993: 86, pl. 18: 1, 2.

Holotype: Complete shell ZPAL Bp 60/2 (Fig. 8C).

Type horizon: Complex C, bed 44, *Palmatolepis transitans* conodont Zone.

Type locality: Wietrznia Ie quarry, SE part of city of Kielce; GPS coordinates: N 50°51’21.0’’, E 20°38’30.6’’.

Derivation of the name: After Kielce, the name of the city where this new species was found.

Diagnosis.—Shell variable in total dimension, up to 20.5 mm in length, transversally subelliptical to subpentagonal in outline; cardinal margin long, broadly obtuse; ventral flanks gently convex, slope sharply at the margins; dorsal fold distinct, with 4–9 costae; ventral sulcus shallow to deep, with concave to flat bottom, and 3–9 costae. From *Flabellulirostrum guerichi* (Baliński, 1979) differs by having wider sulcus and fold and more numerous median costae. *F. afrum* (Drot, 1997) and *F. bergica* (Schmidt, 1975) have more triangular shell outline. *F. wolmericus* (Veevers, 1959) and *F. morzadeci* Brice, 1983 in Brice and Morzadec (1983) have wider shell. From *F. rackii* sp. nov. differs by having convex flanks and round-edged lateral commissure.

Material.—More than 100 well preserved specimens of complete to nearly complete shells and more than 200 fragmentary specimens from Wietrznia Id-W (beds 4, 5, 14, 18, and 31) and Wietrznia Ie sections (beds 29, 30, 43–45, and 48).

Description.—Shell medium sized to large for genus, dorsibiconvex, subelliptical to subpentagonal in outline, widest at about midvalve or slightly more posteriorly; cardinal margin long, broadly obtuse, lateral margins gently rounded, anterior margin truncated to slightly emarginate, anterior commissure strongly uniplicate; lateral commissure of large shells tapered as a result of slight geniculation of valves edges.

Ventral valve gently convex in lateral profile, gently convex when viewed from the anterior, sometimes with concave middle region; flanks gently convex, slope evenly towards the commissure, then more sharply at the margins; interarea wide, limited by blunt borders, beak slightly incurved; sulcus wide, originating about 6–8 mm anterior to the beak, shallow to moderately deep, with concave to flat bottom; tongue long, gently rounded, strongly bent dorsally.

Dorsal valve much deeper than ventral one, regularly arched in lateral profile, and strongly convex in anterior view with elevated tongue and fold; fold originating at about midvalve, anteriorly high, with rounded top.

Shell posteriorly smooth, noncostate, except for fine, flat, radiating capillae (5–8 per mm) and dense concentric growth lines (about 12 per mm); at about 7 mm from umbo capillae

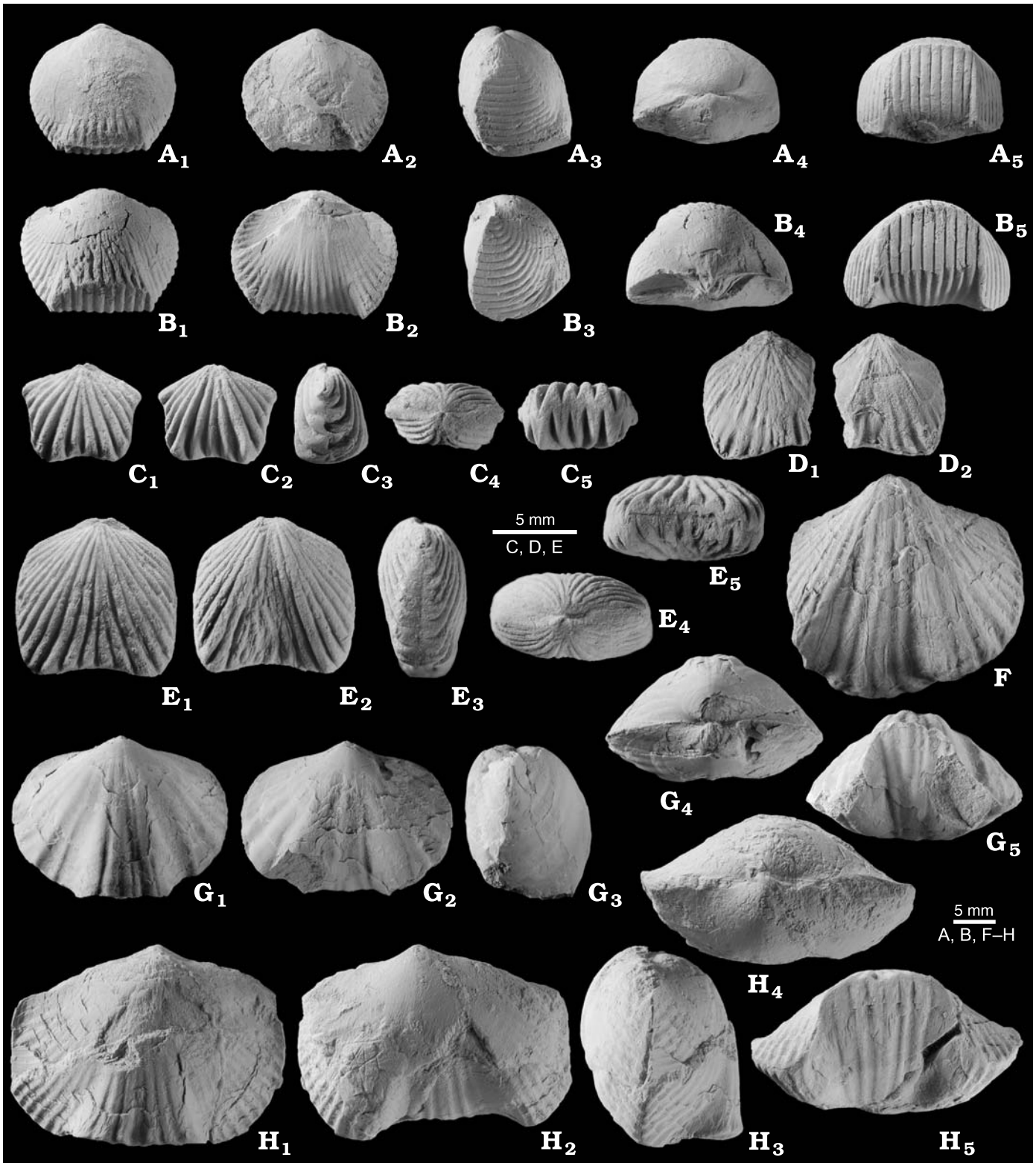

Fig. 7. Rhynchonellid brachiopods from the Frasnian of Wietrznia and Dębnik. **A**, **B**. *Hypothyridina* sp., ZPAL Bp 60/28 (**A**) and GIUS 4-273 Wt/IM-4 (**B**), two complete shells from the middle Wietrznia Beds of Wietrznia Ie and Id-W, respectively, in dorsal (A_1, B_1), ventral (A_2, B_2), lateral (A_3, B_3), posterior (A_4, B_4), and anterior (A_5, B_5) views. **C**. *Fitzroyella alata* Biernat, 1969, GIUS 4-273 Wt/GR-1, complete shell from the middle Wietrznia Beds of Wietrznia Id-W. **D**, **E**. *Fitzroyella* sp. from the middle Wietrznia Beds of Wietrznia Id-W. **D**. Incomplete specimen GIUS 4-273 Wt/IM-7 in dorsal (D_1) and ventral (D_2) views. **E**. Complete shell GIUS 4-273 Wt/GR-2 in dorsal (E_1), ventral (E_2), lateral (E_3), posterior (E_4), and anterior (E_5) views. **F**, **G**. *Plionoptycherhynchus cracoviensis* (Gürich, 1903) from the Nodular Limestone (*Palmatolepis hassi* Zone) of Dębnik. **F**. ZPAL Bp 60/17, fragment of a large shell in ventral view. **G**. ZPAL Bp 60/4, complete shell in dorsal (G_1), ventral (G_2), lateral (G_3), posterior (G_4), and anterior (G_5) views. **H**. *Phlogoiderhynchus polonicus* (Roemer, 1866) from the middle Wietrznia Beds of Wietrznia Id-W, shell GIUS 4-273 Wt/IM-8 in dorsal (H_1), ventral (H_2), lateral (H_3), posterior (H_4), and anterior (H_5) views.

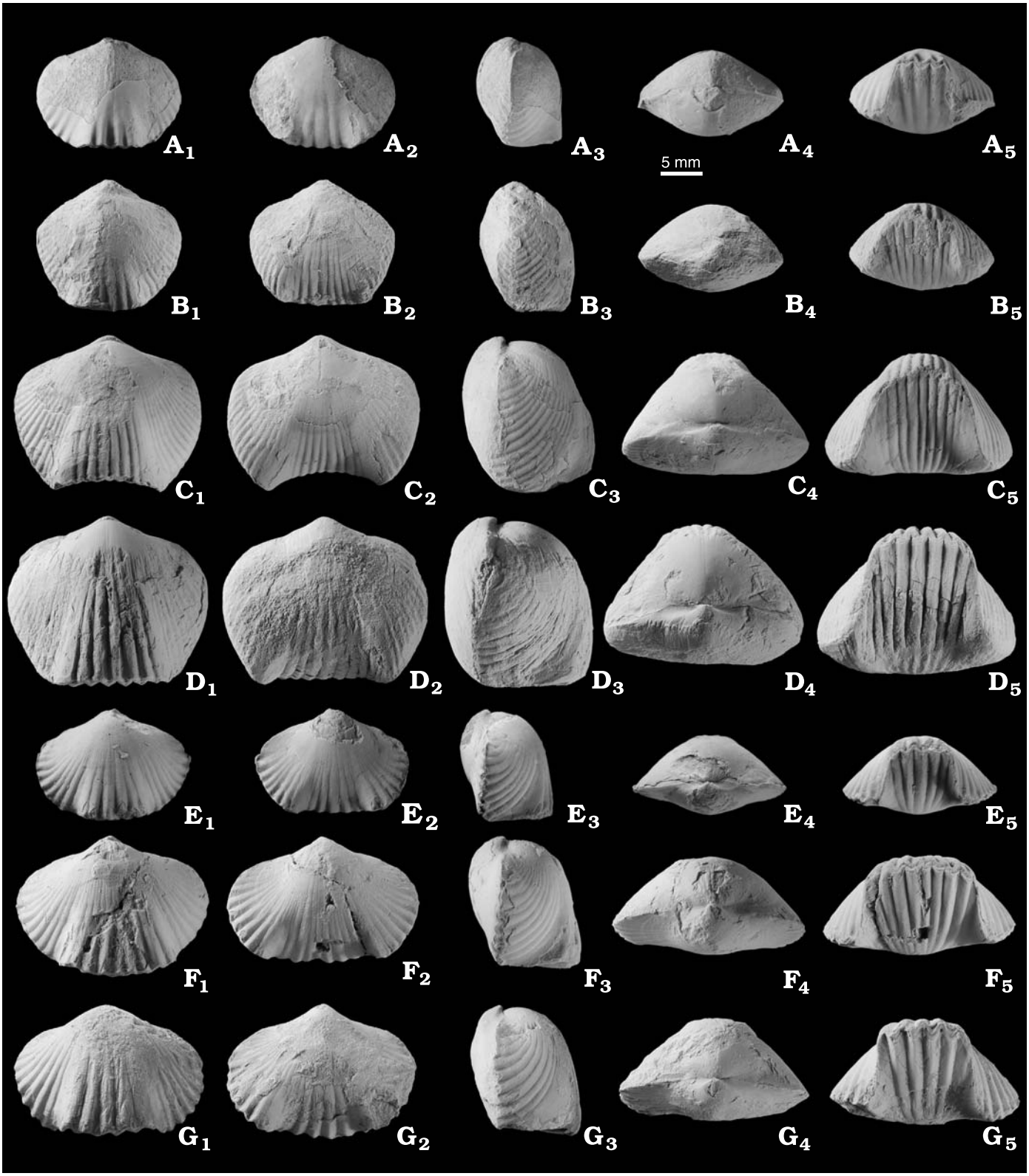

Fig. 8. Rhynchonellid brachiopods from the Frasnian of Wietrznia and Dębnik. **A**. *Flabellulirostrum guerichi* (Baliński, 1979), ZPAL Bp 60/15, complete shell from the Nodular Limestone (*Palmatolepis hassi* Zone) of Dębnik in dorsal (A_1), ventral (A_2), lateral (A_3), posterior (A_4), and anterior (A_5) views. **B–D**. *Flabellulirostrum kielcensis* sp. nov., ZPAL Bp 60/1 (**B**), ZPAL Bp 60/2 (**C**), and GIUS 4-273 Wt/IM-1 (**D**), three shells (**C**—holotype) from the middle Wietrznia Beds of Wietrznia Ie (**B**, **C**) and Id-W (**D**), in dorsal (B_1, C_1, D_1), ventral (B_2, C_2, D_2), lateral (B_3, C_3, D_3), posterior (B_4, C_4, D_4), and anterior (B_5, C_5, D_5) views. **E–G**. *Flabellulirostrum rackii* sp. nov., ZPAL Bp 60/11 (**E**), GIUS 4-273 Wt/IM-9 (**F**), and ZPAL Bp 60/12 (**G**), three shells (**G**—holotype) from the middle Wietrznia Beds of Wietrznia Ie (**E**, **G**) and Id-W (**F**) in dorsal (E_1, F_1, G_1) ventral (E_2, F_2, G_2), lateral (E_3, F_3, G_3), posterior (E_4, F_4, G_4), and anterior (E_5, F_5, G_5) views.

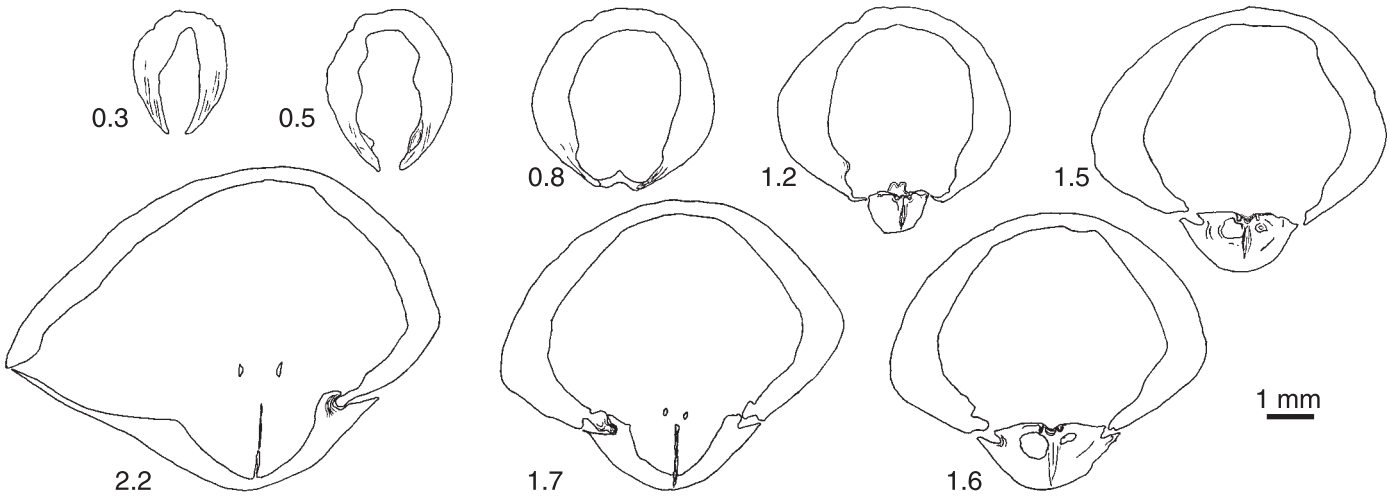

Fig. 9. Serial sections of *Flabellulirostrum kielcensis* sp. nov., ZPAL Bp 60/29, middle Wietrznia Beds of Wietrznia Ie. Numbers refer to distance in mm from ventral umbo.

gradually fade away with simultaneous appearance of radial costae; there are about 5–16 costae on each flank, 4–9 (mean 6.2) costae on fold, and 3–9 costae in sulcus; costae are simple, round-top, median ones sometimes are stronger than those on flanks; parietal costae usually absent, exceptionally one barely discernible parietal costae may be seen but it does not reach anterior margin.

Interior of ventral valve (Fig. 9) without dental plates but with thickened umbonal region. Dorsal valve interior (Fig. 9) with high, rather thin median septum supporting short, horizontal hinge plates; cardinal process distinct; crura closely set, short, delicate, ventrally curved.

Intraspecific variability.—*Flabellulirostrum kielcensis* sp. nov. occurs in Wietrznia Id-W and Wietrznia Ie sections. The occurrence of the species in the former section were studied in details by Makowski (1988; Racki et al. 1993). He discriminated in his material two species of *Flabellulirostrum*, namely *Flabellulirostrum* sp. A, smaller form which occurs in the older stratigraphic horizon (beds 4 and 5), and *Flabellulirostrum* sp. B, which was recovered by him in higher beds (14 and 18). There is no doubt that the younger form is evidently greater that the older, whereas all other shell characters seem to be virtually identical (compare with Fig. 10A, B where smaller and greater shells form two clusters). This difference in the shell dimension could be interpreted more reasonably, however, as environmentally controlled and intraspecific. This point of view is supported by recent recovery in the material from bed 5 of one large shell attaining 19.5 mm in width; this specimen is fully conspecific with specimens from beds 14 and 18.

Remarks.—*Flabellulirostrum kielcensis* sp. nov. is similar in details of the internal shell structure as well as in the general shape and ornamentation of the shell to *Bergalaria guerichi* Baliński, 1979 (= *Flabellulirostrum guerichi*) from the Early Frasnian of the Dębnik anticline, southern Poland. *F. kielcensis* differs from the latter mainly in having wider sulcus and fold, which attains 51–73% of the total shell width, in comparison to 49–55% in the latter species (Fig. 10C). *F. kielcensis* differs from *F. guerichi* also by having more numerous costae on fold and in sulcus, namely 6 and 7 costae on average respectively in comparison to 4.5 and 5.5 costae on average in *F. guerichi* (Fig. 10D). It is also noteworthy that the species from Wietrznia seems to be generally a little larger and thicker.

The new species differs from *Bergalaria bergica* Schmidt, 1975 (= *Flabellulirostrum bergica*) from the earliest Frasnian of Bergisches Land by having not as triangular outline of the shell and by costation which in the latter is confined to more anterior region of the shell. *Flabellulirostrum afrum* (Drot, 1971) has also more triangular shell outline and shorter, more acute cardinal margin (see Drot 1971, 1982).

Flabellulirostrum kielcensis sp. nov. differs markedly from *F. morzadeci* Brice, 1983 in Brice and Morzadec (1983) from the Late Givetian of Massif Armoricain, France (see Brice and Morzadec 1983), by having transversally elliptical to subpentagonal outline of the shell whereas the latter is longitudinally suboval and possesses more acute cardinal margin and more numerous costae. *F. kielcensis* sp. nov. is wider and has less acute and longer cardinal margin than *F. wolmericus* (Veevers, 1959) described from the Sadler Formation (Early Frasnian) of the Fitzroy Basin, Western Australia.

The distinction of this species from *F. rackii* sp. nov. is discussed under the remarks on the latter species.

Occurrence.—*Flabellulirostrum kielcensis* sp. nov. seems to be one of the most common brachiopod species in the Frasnian of the Wietrznia I quarry. Its smaller phenotype is numerous in beds 4 and 5 of Id-W section. Larger phenotype prevails in beds 14, 18, and 31 of the section as well as in beds 29, 30, and 43–45 of the Ie section. All occurrences represent *Palmatolepis transitans* conodont Zone.

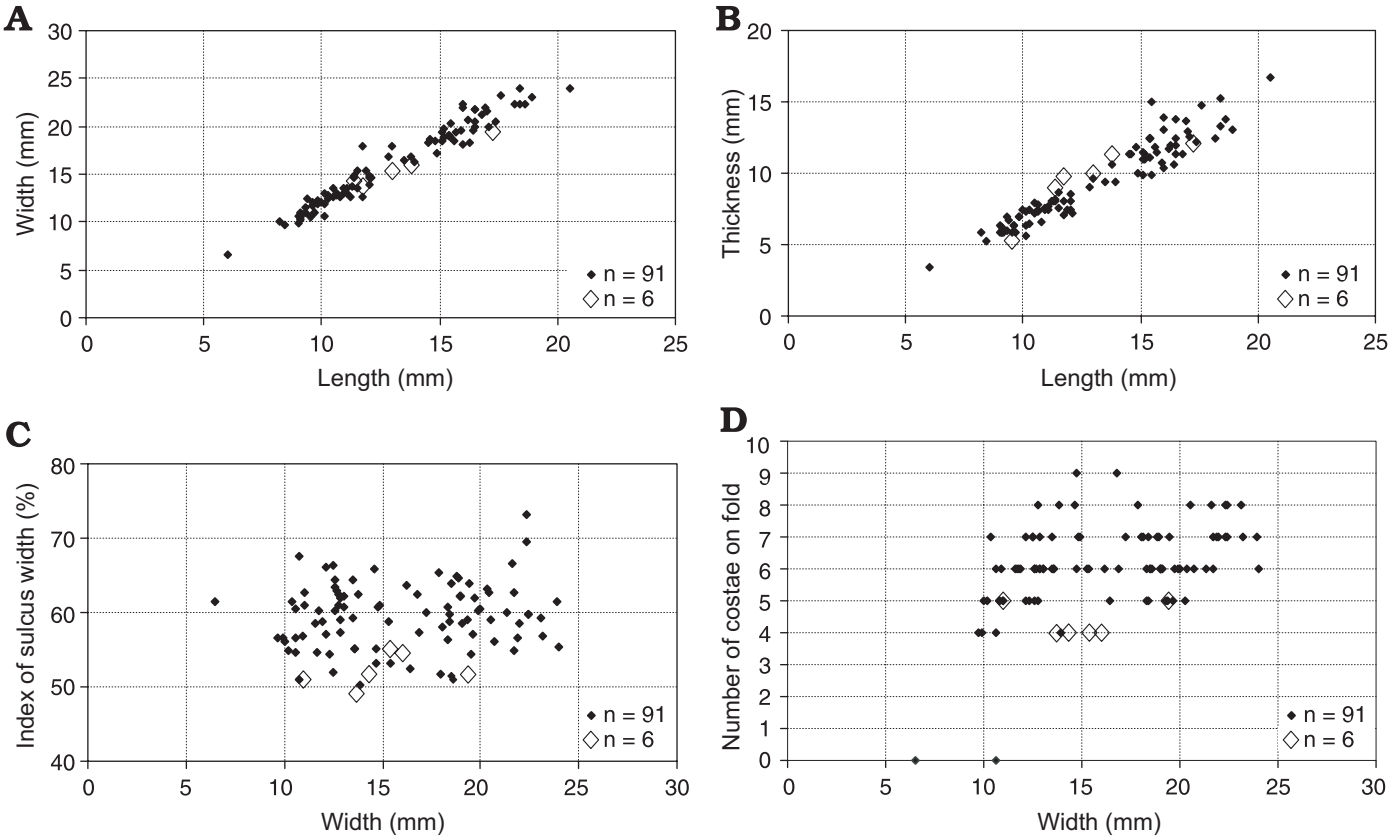

Fig. 10. Scatter diagrams of shell width to shell length (**A**), shell thickness to shell length (**B**), sulcus width to shell width (**C**), and number of costae on fold to shell width ratios in *Flabellulirostrum kielcensis* sp. nov. from Wietrznia Id-W and Ie Wietrznia (solid diamonts) and *Flabellulirostrum guerichi* (Baliński, 1979) from Dębnik (open diamonts).

Flabellulirostrum rackii sp. nov.

Figs. 8E–G, 11, 12.

Holotype: Complete shell ZPAL Bp 60/12 (Fig. 8G).

Type horizon: Complex C, bed 44, *Palmatolepis transitans* conodont Zone.

Type locality: Wietrznia Ie quarry, SE part of city of Kielce; GPS coordinates: N 50°51'21.0'', E 20°38'30.6''.

Derivation of the name: In honour of Professor Grzegorz Racki, in recognition of his contribution to the knowledge of geology and Devonian brachiopods of the Holy Cross Mountains.

Diagnosis.—Shell up to 17.1 mm in length, widely elliptical in outline, widest at about midlength, with long cardinal margin, flat to more often concave ventral flanks in anterior view, with 5–9 costae; sulcus wide, with slightly convex bottom, widening rapidly anteriorly; fold with flat to slightly convex top and 5–9 (mean 6) costae. Differs from other species of the genus by having wider shell. From close *F. kielcensis* sp. nov. it differs by having flat to concave flanks and sharp-edged lateral commissure.

Material.—Thirty nine complete shells and 42 fragments of shells and single valves from Wietrznia Id-W (beds 4, 14, and 18) and Ie sections (beds 43–45 and 48). The species is most numerous in bed 18 of Wietrznia Id-W and beds 44–45 of the Wietrznia Ie sections (Figs. 2, 3).

Description.—Shell medium sized for genus, dorsibiconvex, widely elliptical in outline with the greatest width at about midlength. The cardinal margin broadly obtuse, lateral margins rounded, lateral commissure sharp-edged, anterior margin truncated, anterior commissure strongly uniplicate.

Ventral valve gently convex in lateral profile, beak erect to slightly incurved; flanks sloping gently from the umbonal region, flat to more often concave in anterior view; sulcus wide, originating about 6–7 mm anterior to beak, with slightly convex bottom, widening rapidly and forming long, wide, distally slightly rounded tongue; sulcus bounded clearly from flanks, anteriorly the bounding area projects often forming spur-like extensions.

Dorsal valve moderately convex in lateral profile, sometimes with flattened anterior; regularly domed in anterior view; fold originating about the midvalve, with slightly convex to almost flat top.

Shell without costae in posterior half but covered by fine, flat, radiating capillae (about 4–8 per mm); anterior surface without capillae but costate, costae strong, separated by narrow interspaces, generally with rounded top, sometimes median costae become higher and acute at the commissure; costae simple, divisions or intercalations not observed, flanks marked by 5–9 costae, fold with 5–9 (mean 6; Fig. 12), and sulcus with 4–8 costae; parietal costae usually absent, excep-

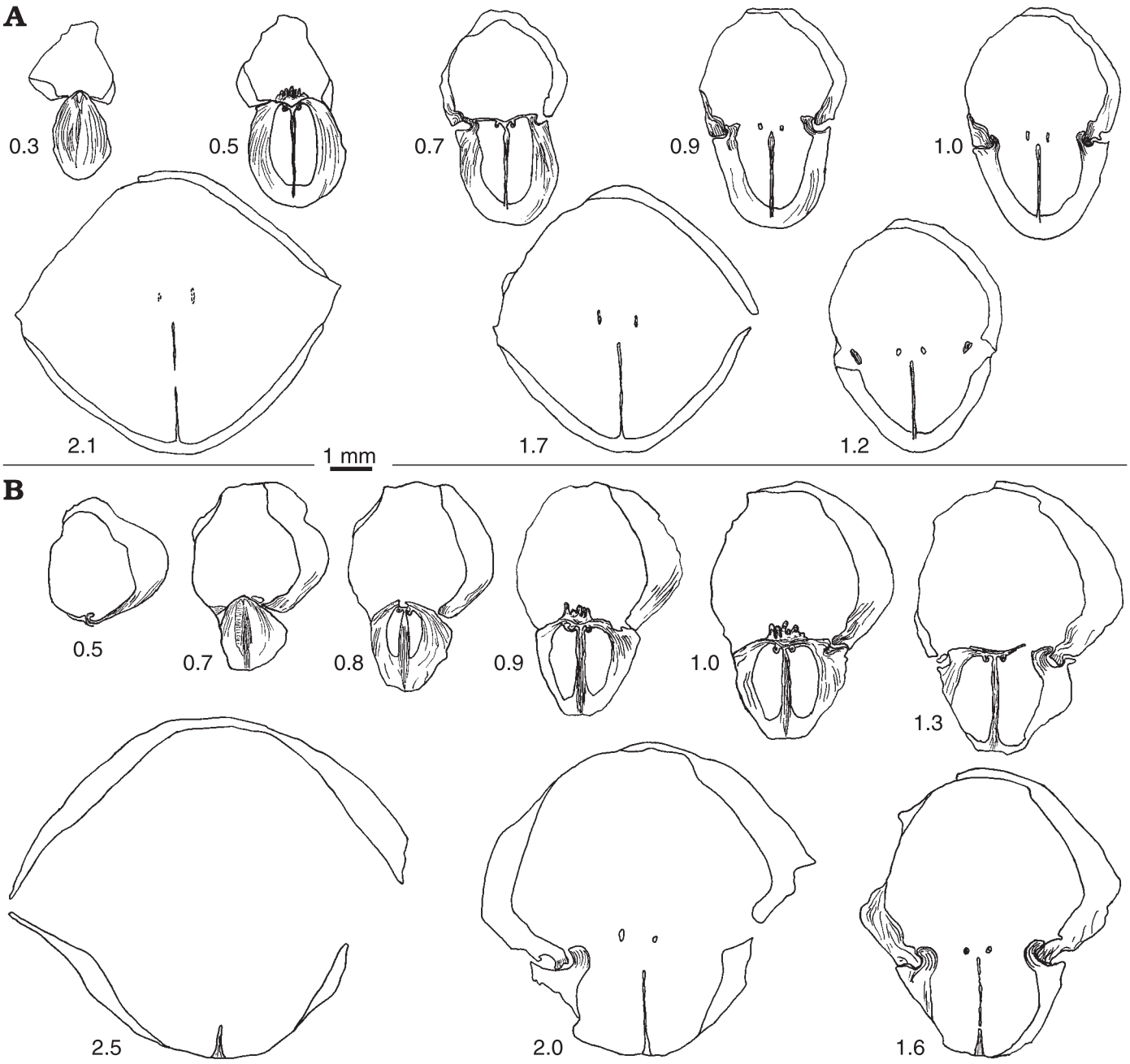

Fig. 11. Serial sections of two shells of *Flabellulirostrum rackii* sp. nov., ZPAL Bp 60/30 (**A**) and ZPAL Bp 60/31 (**B**), middle Wietrznia Beds of Wietrznia Ie. Numbers refer to distance in mm from ventral umbo.

tionally up to two obscure costae may be traced with difficulties. On several shells median costae are wider and stronger than lateral ones.

Interior of ventral valve (Fig. 11) without dental plates, with thickened umbonal region. Dorsal valve interior (Fig. 11) with high, strong median septum supporting short, horizontal hinge plates; cardinal process large, wide, with distinct longitudinal crenulation; crura closely set, short, with ventrally curved tips.

Remarks.—This species occurs in the same beds together with a larger phenotype of *Flabellulirostrum kielcensis* sp. nov. For the first glance both forms seem to be conspecific but detailed study revealed that there are important differences between them. The most important and consistent difference is in the shape of ventral flanks which in *F. rackii* are flat to more often concave, whereas in *F. kielcensis* sp. nov. they are convex. They differ also in the shape of lateral commissure which is sharp-edged in the former but blunt, more round-edged in the latter. The bottom of the tongue is flat to convex in *F. rackii* but flat to concave in *F. kielcensis*.

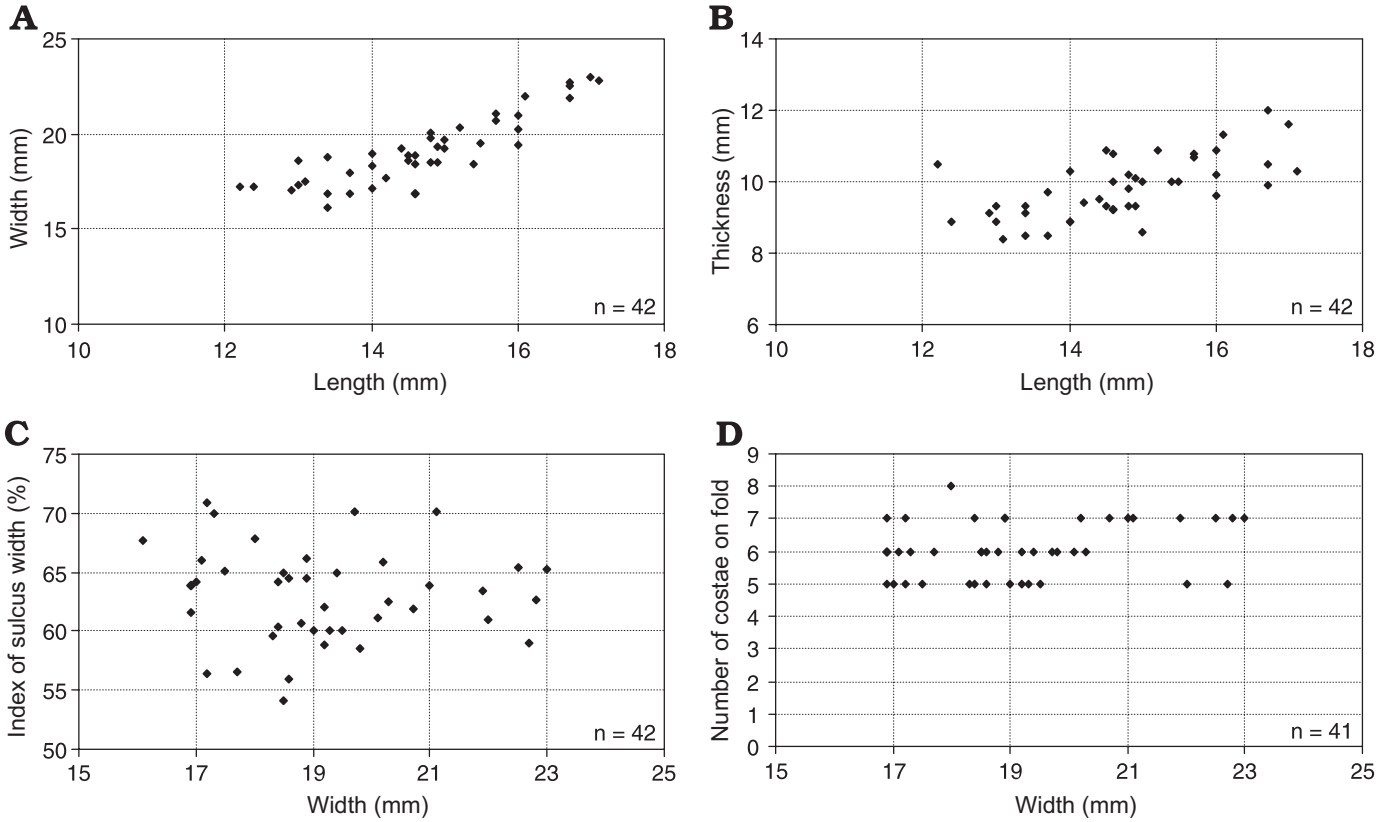

Fig. 12. Scatter diagrams of shell width to shell length (**A**), shell thickness to shell length (**B**), sulcus width to shell width (**C**), and number of costae on fold to shell width (**D**) ratios in *Flabellulirostrum rackii* sp. nov. from Wietrznia.

The former species differs also in its slightly wider outline and in having very distinct, spur-like lateral borders of the ventral sulcus, which in the latter is rounded and less conspicuous.

Occurrence.—The species occurs in the Wietrznia Id-W and Wietrznia Ie sections; these represent *Palmatolepis transitans* conodont Zone.

Flabellulirostrum guerichi (Baliński, 1979)

Fig. 8A.

1979 *Bergalaria guerichi* sp. nov.; Baliński 1979: 50–52, pl. 7: 4–7; pl. 8: 10; fig. 17.

2003 *Flabellulirostrum guerichi* (Baliński, 1979); Baliński in Baliński et al. 2003: 212, pl. 167: 1.

Material.—One complete shell and three fragments from northern quarry at Dębnik in addition to the collection described earlier (see Baliński 1979).

Remarks.—This species was described in details by Baliński (1979). For comparison of *Flabellulirostrum guerichi* with *F. kielcensis* sp. nov. see under discussion of the latter species.

Occurrence.—The species is known only from the Dębnik anticline. It was found earlier only in Rokiczany Dół ravine (Baliński 1979) but now it has been recovered also from the highest beds of the northern quarry near village of Dębnik where it occurs in *Plionoptycherhynchus cracoviensis* local brachiopod Zone (see Baliński 1979).

Family Hypothyridinidae Rzhonsnitskaya, 1956

Genus *Hypothyridina* Buckman, 1906

Type species: *Atrypa cuboides* Sowerby, 1840; Givetian, Great Britain.

Hypothyridina sp.

Fig. 7A, B.

Material.—Eleven complete shells and 14 fragments of shells and valves from Wietrznia Id-W (beds 4, 5, and 14) and Ie (beds 29–30, 50–51, 60, and 66) sections. Specimens partially to strongly decorticated, especially in their posterior region.

Description.—Shell medium sized to small for the genus, attaining up to about 16 mm in length, subpentagonal in outline, wider than long, strongly dorsibiconvex; lateral margins rounded, anterior margin truncated to very weakly arched, anterior commissure strongly uniplicate.

Ventral valve weakly convex with slightly concave flanks in anterior view; sulcus very weak, although wide, originating about 7 mm from the umbo, with slightly convex bottom; tongue long, distally almost straight to slightly arched, with subparallel sides.

Dorsal valve very deep with inflated umbonal region which, however, does not extend beyond ventral beak; flanks strongly curved, almost vertical; fold very low, with weakly convex top.

Costae low, flattened, and simple, starting at some distance

from the umbonal regions, separated by very narrow furrows. There are about 9 median costae and 10–12 lateral ones.

Interior poorly known; dental plates can be identified on the internal shell moulds.

Remarks.—This small collection of strongly decorticated shells from Wietrznia quarry exhibit some futures characteristic for cosmopolitan genus *Hypothyridina* Buckman. In his revision of some hypothyridinids Sartenaer (2003) discussed the taxonomic problems of the genus and its allies. He concluded that the group urgently needs further studies especially because *Hypothyridina* is still inadequately known and became a catch-all name. Recently a few new hypothyridinid genera were described from different stratigraphic intervals, i.e., *Glosshypothyridina* Rzhonsnitskaya, 1978 from the upper Eifelian, *Xiaobangdaia* Wang, 1985 from the upper Famennian, and *Tullypothyridina* Sartenaer, 2003 from the upper Givetian.

Occurrence.—The species was recovered in Wietrznia Id-W and Wietrznia Ie sections; all occurrences represent *Palmatolepis transitans* conodont Zone.

Superfamily Camarotoechioidea Schuchert, 1929 in Schuchert and LeVene 1929

Family Leiorhynchidae Stainbrook, 1945

Genus *Plionoptycherhynchus* Sartenaer, 1979

Type species: *Plionoptycherhynchus exformosus* Sartenaer, 1979; Frasnian, France.

Plionoptycherhynchus cracoviensis (Gürich, 1903)

Fig. 7F, G.

1903 *Leiorhynchus Cracoviensis* Gür.; Gürich 1903: 149–150, pl. 2: 14; fig. 3.
1979 *Calvinaria cracoviensis* (Gürich, 1903); Baliński 1979: 38–40, pl. 5: 1–5; fig. 12A, B.
2003 *Plionoptycherhynchus cracoviensis* (Gürich, 1903); Baliński in Baliński et al. 2003: 210, pl. 166: 7.

Material.—One complete shell and 13 fragments from northern quarry at Dębnik in addition to the collection described earlier from Rokiczany Dół ravine north of Dębnik (see Baliński 1979).

Remarks.—The species was revised by Baliński (1979). It was then known only from dark-gray biopelmicrites of Rokiczany Dół ravine for which it was characteristic fossil (*Plionoptycherhynchus cracoviensis* local brachiopod Zone). During present investigation the species was recovered also in the highest beds of the west wall of the northern quarry at Dębnik.

Occurrence.—Upper part of Rokiczany Dół ravine and highest beds of the northern quarry at village of Dębnik.

Family Septalariidae Havlíček, 1960

Genus *Phlogoiderhynchus* Sartenaer, 1970

Type species: *Uncinulus arefactus* Veevers, 1959; Early Frasnian, Australia.

Phlogoiderhynchus polonicus (Roemer, 1866)

Figs. 5A, 7H.

1866 *Camarotoechia*? *polonica*; Roemer 1866: 676, pl. 13: 9, 10.
1896 *Camarotoechia polonica* F. Roemer; Gürich 1896: 280, pl. 7: 8.
1975 *Phlogoiderhynchus polonicus* (Roemer, 1866); Biernat and Szulczewski 1975: 203–215, pls. 21–28, fig. 2.
1988 *Phlogoiderhynchus polonicus* (Roemer); Makowski 1988: pl. 10: 8, 9.
1993 *Phlogoiderhynchus polonicus*; Makowski in Racki et al. 1993: pl. 18: 3.

Material.—Twenty two complete shells and 14 fragments from Wietrznia Id-W section (beds 4, 14, 18, and 31), three shells from Wietrznia Ie section (beds 60 and 92) as well as one complete shell from loose block found to the west of Id-W section. Two nearly complete shells and 23 fragments from Kostomłoty V quarry, as well as thirty complete to nearly complete shells and 59 fragments from Kostomłoty II quarry.

Remarks.—The species was revised in great detail by Biernat and Szulczewski (1975). The authors carefully elaborated external and internal characters of the shell including their variability. It is noteworthy that shells of *Phlogoiderhynchus polonicus* recently recovered from Kostomłoty are frequently colonised by discinoid *Roemerella*? sp. (Fig. 5).

Occurrence.—The species occurs in the latest part of Givetian to Middle Frasnian marls, marly limestones, and limestones of several localities in the Holy Cross Mountains: Jaźwica, Kowala, Sosnówka, Śluchowice, Kostomłoty, Szydłówek, Józefka, Chęciny, and Wietrznia (Biernat and Szulczewski 1975; Racki 1993b). It is regarded as a good characteristic fossil for the Early Frasnian deposits and useful species for correlation of the north and south basinal regions of the Holy Cross Mountains (Biernat and Szulczewski 1975) but Racki (1993b) and Sartenaer and Racki (1992) noted some diachronism in spreading of the species to the southern basins.

Superfamily Pugnacoidea Rzhonsnitskaya, 1956

Family Pugnacidae Rzhonsnitskaya, 1956

Genus *Coeloterorhynchus* Sartenaer, 1966

Type species: *Coeloterorhynchus tabasensis* Sartenaer, 1966; Middle and Late Frasnian, Iran.

Coeloterorhynchus dillanus (Schmidt, 1941)

Figs. 13, 14D–F.

1941 *Pugnax acuminatus dillanus* n. subsp.; Schmidt 1941: 284–285, pl. 1: 2–4.
1971 *Coeloterorhynchus dillanus* (Herta Schmidt, 1941); Brice 1971: 79, pl. 3: 7–9; fig. 3.
1988 "*Parapugnax*" sp.; Makowski 1988: pl. 12: 3, 4, 6, 13, 14.
1990 *Coeloterorhynchus dillanus* (Schmidt, 1941); Budziszewska 1990: 32–33, pl. 5: 1, 2.
1990 *Coeloterorhynchus magnificum* Cooper and Dutro, 1982; Budziszewska 1990: 33–35, pl. 6: 1–4.
1993 "*Parapugnax*" sp.; Makowski in Racki et al. 1993: pl. 8: 5.

Material.—55 more-or-less complete shells that are usually

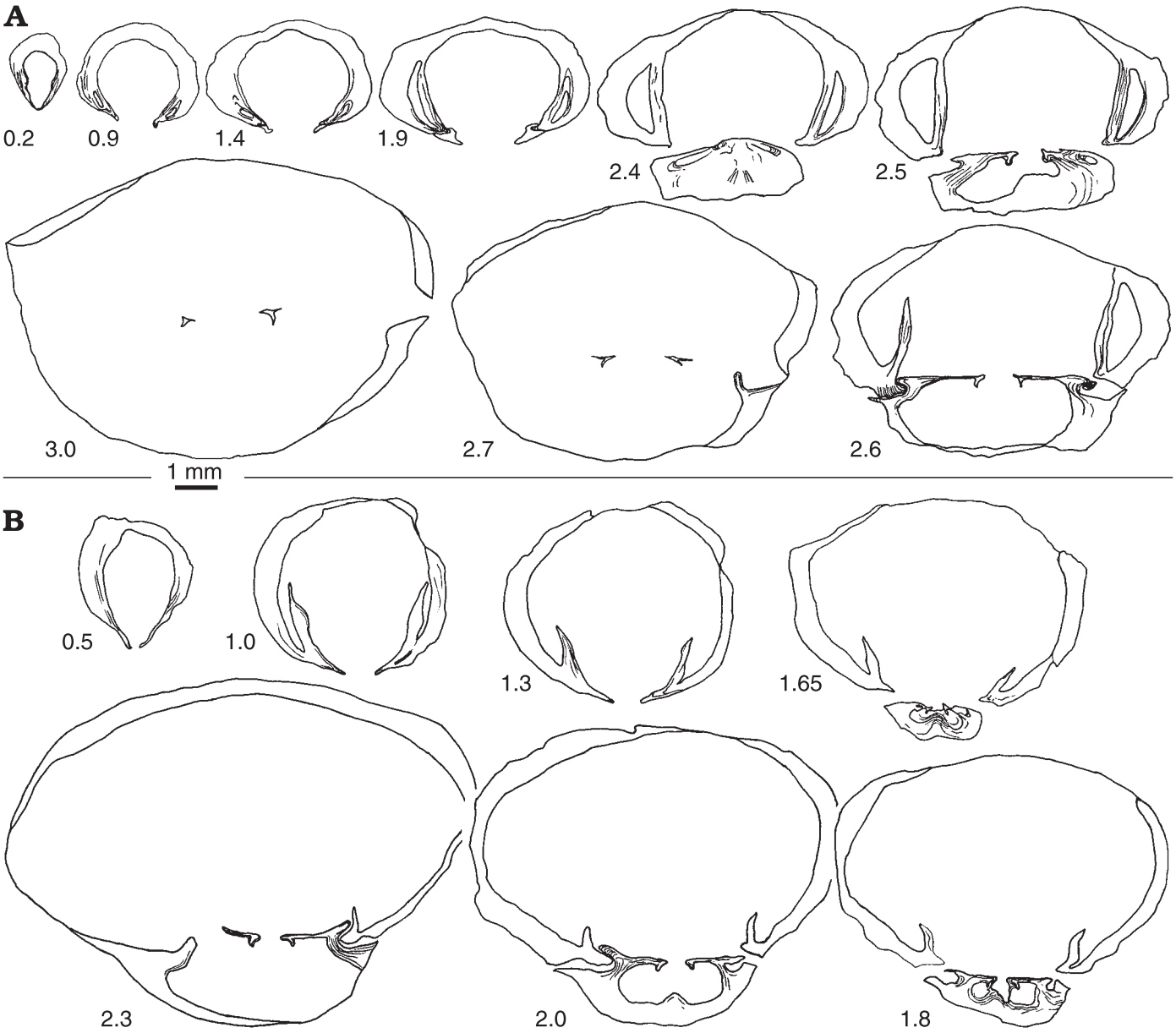

Fig. 13. Serial sections of two shells of *Coeloterorhynchus dillanus* (Schmidt, 1941), ZPAL Bp 60/32 (**A**) and ZPAL Bp 60/33 (**B**), middle Wietrznia Beds of Wietrznia Ie. Numbers refer to distance in mm from ventral umbo.

strongly exfoliated and 65 fragments. Most of the collection comes from bed 14 of set C in Wietrznia Id-W section and beds 44 and 45 of the same set in Wietrznia Ie section (see Figs. 2 and 3 for details).

Description.—Shell medium to large sized, wider than long, transversely elliptical in outline, strongly dorsibiconvex; cardinal margin broadly arched to slightly angular, lateral margins rounded, anterior margin truncate to slightly emarginate, anterior commissure strongly uniplicate.

Ventral valve with weakly convex flanks and deeply excavated wide sulcus originating about 7–8 mm from the umbo; tongue high, rounded and serrate, with concave to flat, costate bottom, in large shells slightly bent dorsally.

Dorsal valve strongly domed in anterior view; in lateral view it is posteriorly convex but flattened in anterior region; fold very high but laterally smoothly grades into flanks, which are strongly expanded ventrally.

Shell surface smooth except for marginal parts of valves which are costate; flanks with up to five usually weak costae, fold with 2–6 costae (usually 3 or 4), sulcus with 1–5 costae (usually 2 or 3), costae on fold shorter but stronger than those in sulcus. Microornamentation rarely observed, in the form of extremely weak radial capillae and concentric growth lines seen on preserved patches of the primary shell layer. However, the traces of the capillae can be also recognised on specimens with exfoliated primary

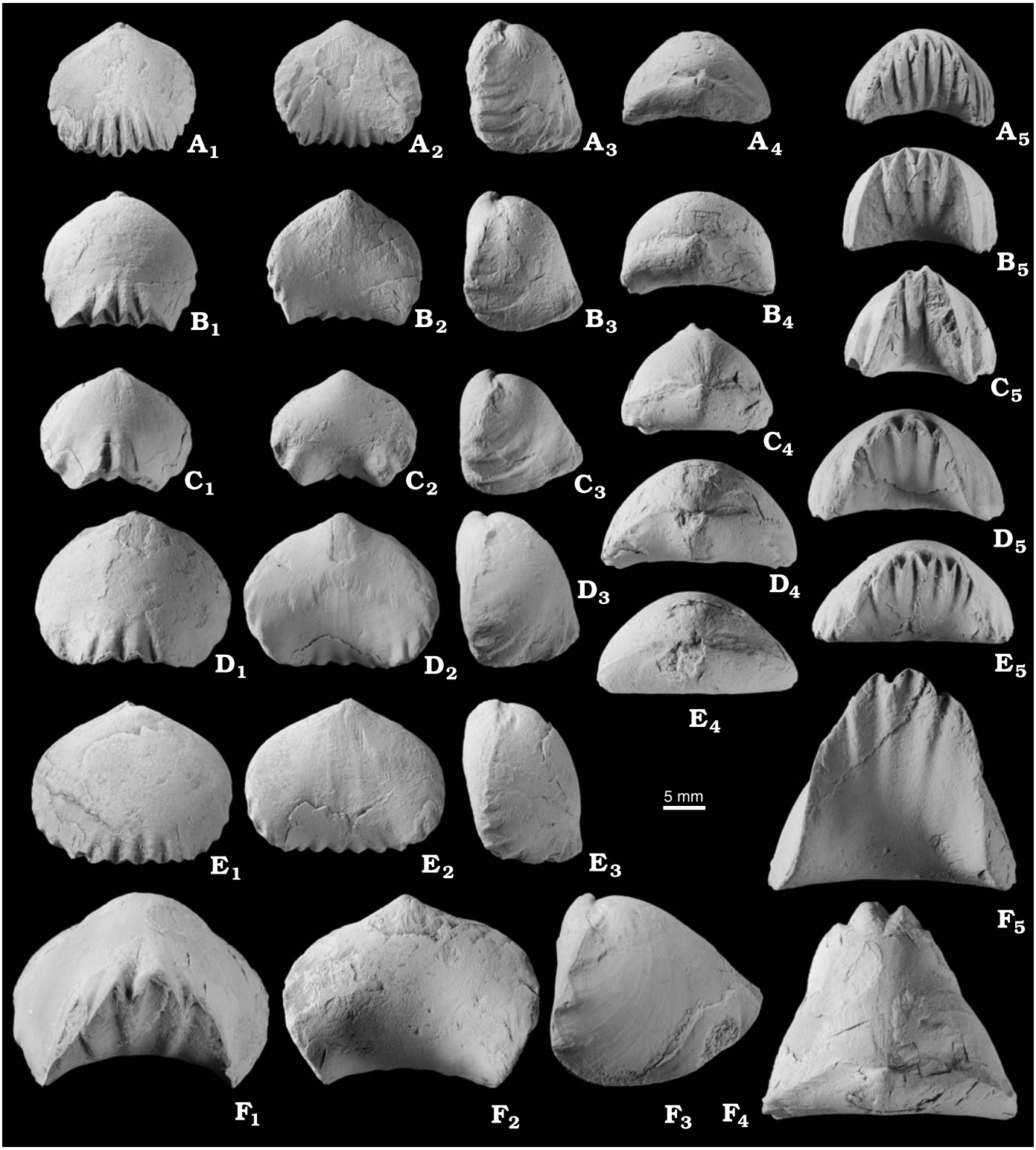

Fig. 14. Rhynchonellid brachiopods from the middle Wietrznia Beds of Wietrznia Ie (**A**) and Id-W (**B**–**F**). **A**–**C**. *Coeloterorhynchus schucherti* (Stainbrook, 1945), ZPAL Bp 60/7 (**A**), GIUS 4-273 Wt/IM-12 (**B**), and GIUS 4-273 Wt/IM-13 (**C**), three complete shells in dorsal (A_1, B_1, C_1), ventral (A_2, B_2, C_2), lateral (A_3, B_3, C_3), posterior (A_4, B_4, C_4), and anterior (A_5, B_5, C_5) views. **D**–**F**. *Coeloterorhynchus dillanus* (Schmidt, 1941), GIUS 4-273 Wt/EB-1 (**D**), GIUS 4-273 Wt/EB-2 (**E**), and GIUS 4-273 Wt/EB-6 (**F**), three complete shells in dorsal (D_1, E_1, F_1), ventral (D_2, E_2, F_2), lateral (D_3, E_3, F_3), posterior (D_4, E_4, F_4), and anterior (D_5, E_5, F_5) views.

layer but with well preserved external surface of the fibrous secondary shell layer.

Interior of the ventral valve with short subparallel to slightly divergent dental plates. Dorsal valve without median

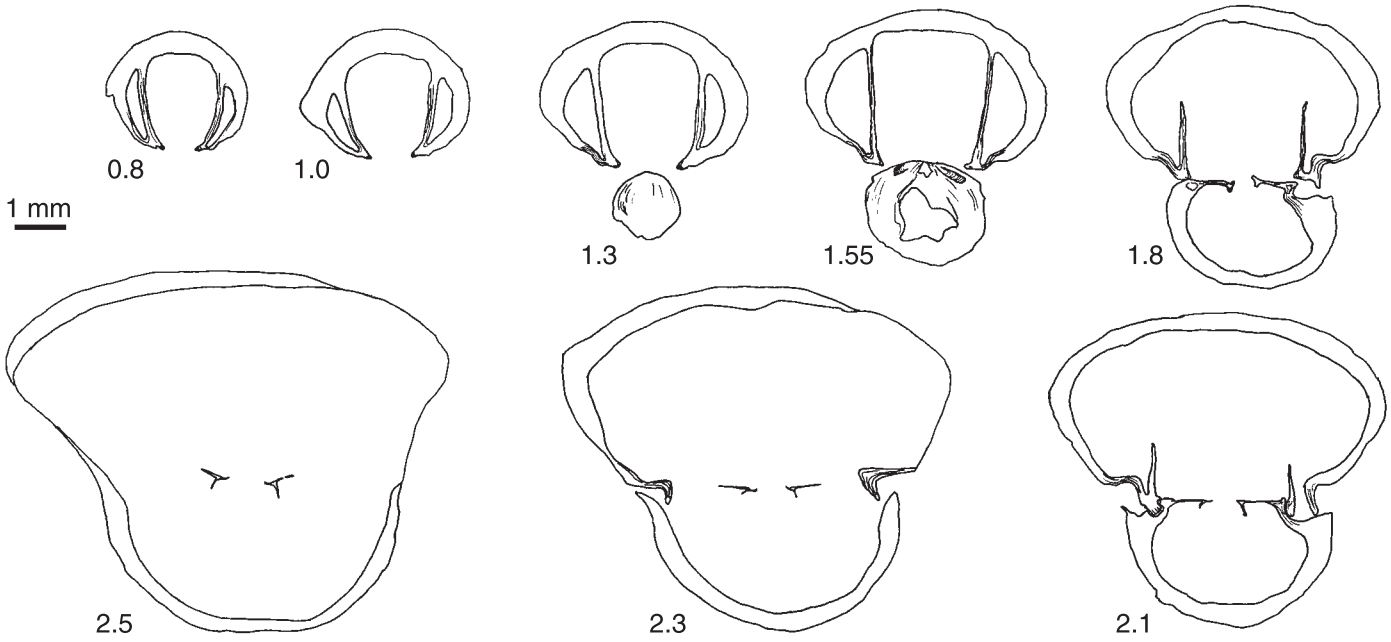

Fig. 15. Serial sections of the shell of *Coeloterorhynchus schucherti* (Stainbrook, 1945), ZPAL Bp 60/34, middle Wietrznia Beds of Wietrznia Ie. Numbers refer to distance in mm from ventral umbo.

septum but with short median thickening or ridge (Fig. 13); hinge plates discrete.

Remarks.—The specimens from Wietrznia show great variability in general shell dimensions and shape, degree of its costation, and in width and depth of the ventral sulcus. They have a close affinity to *Coeloterorhynchus dillanus* (Schmidt, 1941) which was described from the Frasnian Iberger Kalk of Germany. Unfortunately, the species was inadequately figured by that author thus making the assessing range of its variability difficult. It seems, however, that both forms have the same shell shape, outline, costation and similarly developed ventral sulcus and tongue. Some specimens from Wietrznia have stronger median costae but this difference might be immaterial from the reason mentioned above. The specimens described here demonstrate considerable variability in width of the ventral sulcus which may be wider or narrower than that in the German specimens.

The specimens of *Coeloterorhynchus dillanus* described from the Frasnian of Morocco by Brice (1971) are generally very similar to type specimens from Germany and to the specimens here described but differ mainly by apparently more compressed shell laterally.

Polish specimens are also similar in many respects to *Coeloterorhynchus magnificum* Cooper and Dutro, 1982 described from the Sly Gap Formation of New Mexico (see also Budziszewska 1990). Minor differences are seen only in greater shell dimensions and occasionally in slightly wider shell attained by some of the studied specimens. It seems that both forms are very close.

Occurrence.—This is fairly common species in set C of Wietrznia Id-W and Ie sections. These occurrences represent *Palmatolepis transitans* conodont Zone. It was originally described from the Iberger Limestone of Langenaubach and Winterberg, Germany (Schmidt 1941). The species was apparently also recovered by the present author in the Frasnian brachiopod limestone of Elbingerode, Germany.

Coeloterorhynchus schucherti (Stainbrook, 1945)

Figs. 14A–C, 15.

1945 *Pugnoides schucherti* Stainbrook, n. sp.; Stainbrook 1945: 43, fig. 1: 13, pl. 4: 15–19.

1979 *Parapugnax schucherti* (Stainbrook, 1945); Baliński 1979: 36–37, fig. 11B–C, pl. 4: 4–5, 7.

1985 *Coeloterorhynchus schucherti* Stainbrook, 1945; Baliński 1985: 242–243, pl. 21: A–D; pl. 22: 1–2.

1990 *Parapugnax schucherti* (Stainbrook, 1945); Budziszewska 1990: 37–38, pl. 8: 1.

1993 "*Parapugnax*"; Makowski in Racki et al. 1993: pl. 18: 5.

Material.—Ten complete shells and 11 fragmentary specimens from Wietrznia Id-W (beds 4, 14, and 18) and Wietrznia Ie sections (beds 43–45, 65, and 66).

Description.—Shell medium to small sized for genus, strongly dorsibiconvex, subpentagonal in outline with the greatest width at about midlength. The cardinal margin broadly obtuse forming an angle of 107–120°, lateral margins rounded, anterior margin truncated, anterior commissure strongly uniplicate.

Ventral valve gently convex, sulcus very wide, uniformly concave and poorly bounded laterally, widening rapidly and forming long, wide, distally slightly rounded tongue.

Dorsal valve convex in lateral profile, narrowly domed in anterior view, with swollen umbonal region; lateral flanks

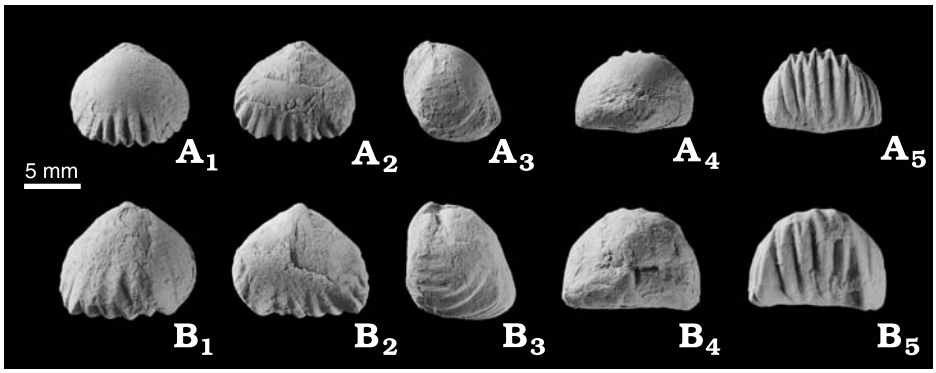

Fig. 16. Rhynchonellid brachiopod *Coeloterorhynchus* aff. *kayserii* (Rigaux, 1908) from the middle Wietrznia Beds of Wietrznia Id-W. **A**, **B**. Two shells GIUS 4-273 Wt/EB-4 (**A**) and GIUS 4-273 Wt/EB-3 (**B**) in dorsal (A_1, B_1), ventral (A_2, B_2), lateral (A_3, B_3), posterior (A_4, B_4), and anterior (A_5, B_5) views.

strongly expanded ventrally; fold originating about the mid-valve, poorly defined with convex top.

Shell smooth, noncostate in posterior half but covered by fine, flat, often difficult to trace, radiating capillae (about 6 per mm); anterior surface costate, median costae strong, angular, simple; flanks marked by up to 7 flattened costae, fold with 4–7, and sulcus with 3–6 costae; parietal costae absent or one costa can be observed on each slope; growth lines dense.

Ventral valve interior with short, delicate dental plates. Dorsal interior with horizontal hinge plates; without median septum (Fig. 15).

Remarks.—The specimens here described have strong resemblance to *Pugnoides schucherti* described from the Independence Formation of Iowa by Stainbrook (1945). The species was inadequately figured by him and it is difficult to determine the range of external variability. However, Cooper and Dutro (1982: 77) noted that the Independence species is quite variable. It seems, that the specimens here described fall within the range of variability of Stainbrook's species. The colour shell pattern in *Coeloterorhynchus schucherti* from the Dębnik anticline (southern Poland) was described by Baliński (1985).

Occurrence.—The species was recovered in several layers of Wietrznia Id-W and Ie sections representing *Palmatolepis transitans* conodont Zone (Figs. 2, 3). Earlier it was described from the early part of the Middle Frasnian (Middle and Upper *Polygnathus asymmetricus* Zone; = *Pa. punctata–Pa. hassi* zones) of the Dębnik anticline of southern Poland (Baliński 1979). Originally, it was described as *Pugnoides schucherti* from the Independence Shale of Iowa (Stainbrook 1945).

Coeloterorhynchus aff. *kayserii* (Rigaux, 1908)

Fig. 16A, B.

aff. 1908 *Coeloterorhynchus kayserii* n. sp.; Rigaux 1908: 24, pl. 1: 12.
aff. 1981 *Coeloterorhynchus kayserii* (Rigaux, 1908); Brice 1981: 150–151; pl. 6: 27–30.

Material.—Nine complete to nearly complete and two fragmentarily preserved shells. Majority of the material comes from bed 4 and 14 of Wietrznia Id-W section; two specimens were recovered from bed 48 and 60 of Wietrznia Ie section.

Description.—Shell small averaging about 12 mm in width, wider than long, dorsibiconvex, subpentagonal in outline; cardinal margin obtuse attaining 105–120°, lateral margins rounded, anterior margin truncated, anterior commissure strongly uniplicate and serrate.

Ventral valve gently convex in lateral profile with erect to slightly incurved beak; sulcus wide but rather shallow, originating about valve midlength; tongue long, strongly bent dorsally, often with anteriorly directed top, with slightly concave to convex bottom.

Dorsal valve moderately convex in lateral profile, sometimes with flattened anterior, regularly and highly domed in anterior view, slightly concave near cardinal margin; fold very poorly defined, best marked anteriorly.

Shell smooth in posterior two-third, anteriorly costate; number of median costae very variable, on fold from 3 to 5, occasionally up to 7 costae; flanks with 3–5 costae. Microornamentation rarely preserved in form of delicate radial capillae and concentric growth lines.

Interior of the ventral valve with short, delicate, slightly convergent dental plates. Dorsal interior with thin horizontal hinge plates and very short median myophragm. Other details of the internal shell structure are strongly obliterated due to recrystalization of the shell interior.

Remarks.—The studied specimens are characterised by small shell dimensions, subpentagonal outline, strongly bent dorsally tongue, and variable number of median costae. They are externally most closely related to *Coeloterorhynchus kayserii* (Rigaux, 1908) described by Rigaux (1908) and Brice (1981) from the Formation de Beaulieu (Early Frasnian) of France. The essential difference is, however, in the number of costae on fold and in sulcus which in *C. kayseri* oscillate from two to four whereas in specimens from Wietrznia there are up to seven costae. Also the number of costae on flanks is greater in the latter form attaining 3–5 costae in comparison to 1–3 costae in the former.

Occurrence.—The species is rather uncommon in the studied fauna. It was recovered in several layers of Wietrznia Id-W and Ie sections representing *Palmatolepis transitans* conodont Zone (Figs. 2, 3). In France *C. kayseri* was described from the Formation de Beaulieu of Ferques (Boulonnais); the occurrence is restricted to the *Polygnathus asymmetricus* conodont zone (Brice 1981).

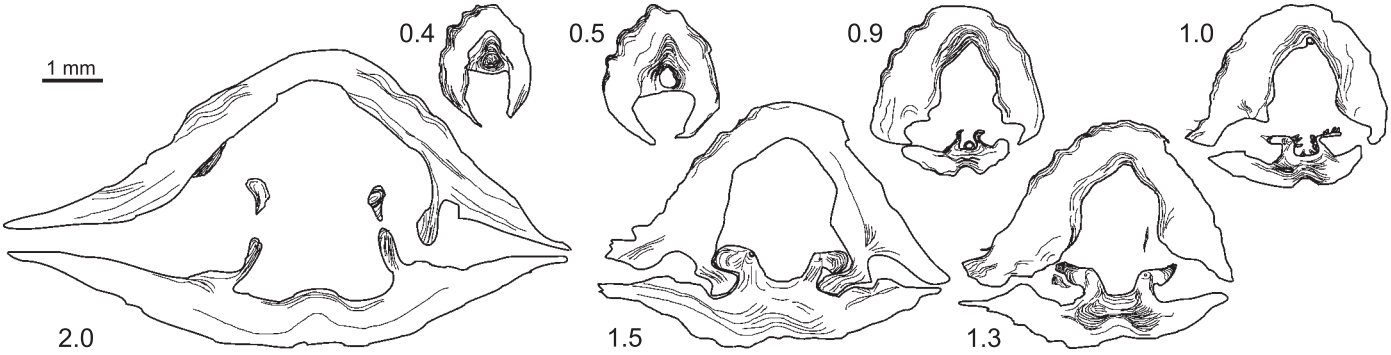

Fig. 17. Serial sections of the shell of *Atryparia* (*Costatrypa*) sp., GIUS 4-273 Wt/EB-5, middle Wietrznia Beds of Wietrznia Id-W. Numbers refer to distance in mm from ventral umbo.

Order Atrypida Rzhonsnitskaya, 1960
Superfamily Atrypoidea Gill, 1871
Family Atrypidae Gill, 1871
Subfamily Atrypinae Gill, 1871
Genus *Atryparia* Copper, 1966
Subgenus *Atryparia* (*Costatrypa*) Copper, 1973

Type species: *Atrypa varicostata* Stainbrook, 1945.

Atryparia (*Costatrypa*) sp.

Figs. 17, 18B.

Material.—Five complete, 10 slightly damaged, and 16 fragmentary shells from Wietrznia Id-W (beds 4 and 14) and Ie (beds 44–45) sections. In addition, two specimens were recovered from loose blocks found between Id-W and Ie sections. Majority of available specimens represent neanic stage.

Description.—Shell medium sized, dorsibiconvex to planoconvex, usually shield shaped, with long, recti-linear hinge margin and rounded hinge corners, slightly wider than long to subequal, widest near hinge; anterior commissure weakly to rarely strongly uniplicate.

Ventral valve gently convex to almost flat, flanks concave; beak strongly incurved, adpressed; presence of pedicle foramen not clear due to damaged apical region of the beak; sulcus weak but in some large specimens producing long and narrow tongue. Dorsal valve more convex to inflated; fold usually weak, observed near the anterior commissure only.

Ribs rather low, 5–9 per 5 mm, sometimes variable in thickness along shell length, thinner near commissure; growth lamellae spaced at 1–3.5 mm, more crowded anteriorly.

Interior of the ventral valve with strong, massive teeth; dental lamellae lacking; thick pedicle callist. Inside the dorsal valve distinct, comblike cardinal process lining inner socket ridges and cardinal pit (Fig. 17); brachial apparatus not preserved in sectioned specimen.

Remarks.—General shell form, its ornamentation and details of the internal structure suggest that described specimens belong to *Atryparia* (*Costatrypa*) Copper, 1973. However, the studied collection, in which neanic specimens predominate, seems to be not sufficient for specific determination. They show general similarity to several species from the early part of the Frasnian of Western Europe and North America. It seems that they are closest to the highly variable externally *A.* (*Costatrypa*) *variabilis* (Godefroid, 1970) from de Neuville Formation, Belgium (Godefroid 1970, 1998). Some large specimens from Wietrznia are almost identical morphologically to *Atryparia rubra* Cooper and Dutro, 1982 from the Oñate Formation of New Mexico (Cooper and Dutro 1982).

Occurrence.—This is uncommon species in lower part of the set C in Wietrznia Id-W and Ie sections representing *Palmatolepis transitans* conodont Zone (Figs. 2, 3).

Subfamily Spinatrypinae Copper, 1978
Genus *Spinatrypina* Rzhonsnitskaya, 1964
Subgenus *Spinatrypina* (*Exatrypa*) Copper, 1967

Type species: *Terebratulites explanatus* Schlotheim, 1820; Frasnian, Germany.

Spinatrypina (*Exatrypa*) cf. *explanata* (Schlotheim, 1820)

Fig. 18C, D.

cf. 1967 *Spinatrypina* (*Exatrypa*) *explanata* (Schlotheim, 1820); Copper 1967: 125–127, text-figs. 7, 8, pl. 20: 1–4.

1998 *Spinatrypina* (*Exatrypa*) *explanata* (Schlotheim, 1820); Racki and Baliński 1998: 284, fig. 11.

Material.—Two complete neanic shells, six slightly damaged and 22 fragments of shells from Wietrznia Id-W (bed 14) and Ie (beds 29–30, 40, and 171) sections. Three incomplete shells were recovered from loose blocks found a few metres west of Id-W section.

Remarks.—The majority of specimens from Wietrznia represent small-sized shells attaining 10–14 mm in length. Only a few specimens in the present collection are larger but, unfortunately, they are very incomplete and do not warrant a satisfactory description. General shell form and its ornamentation, development of ventral interarea, and wide hinge mar-

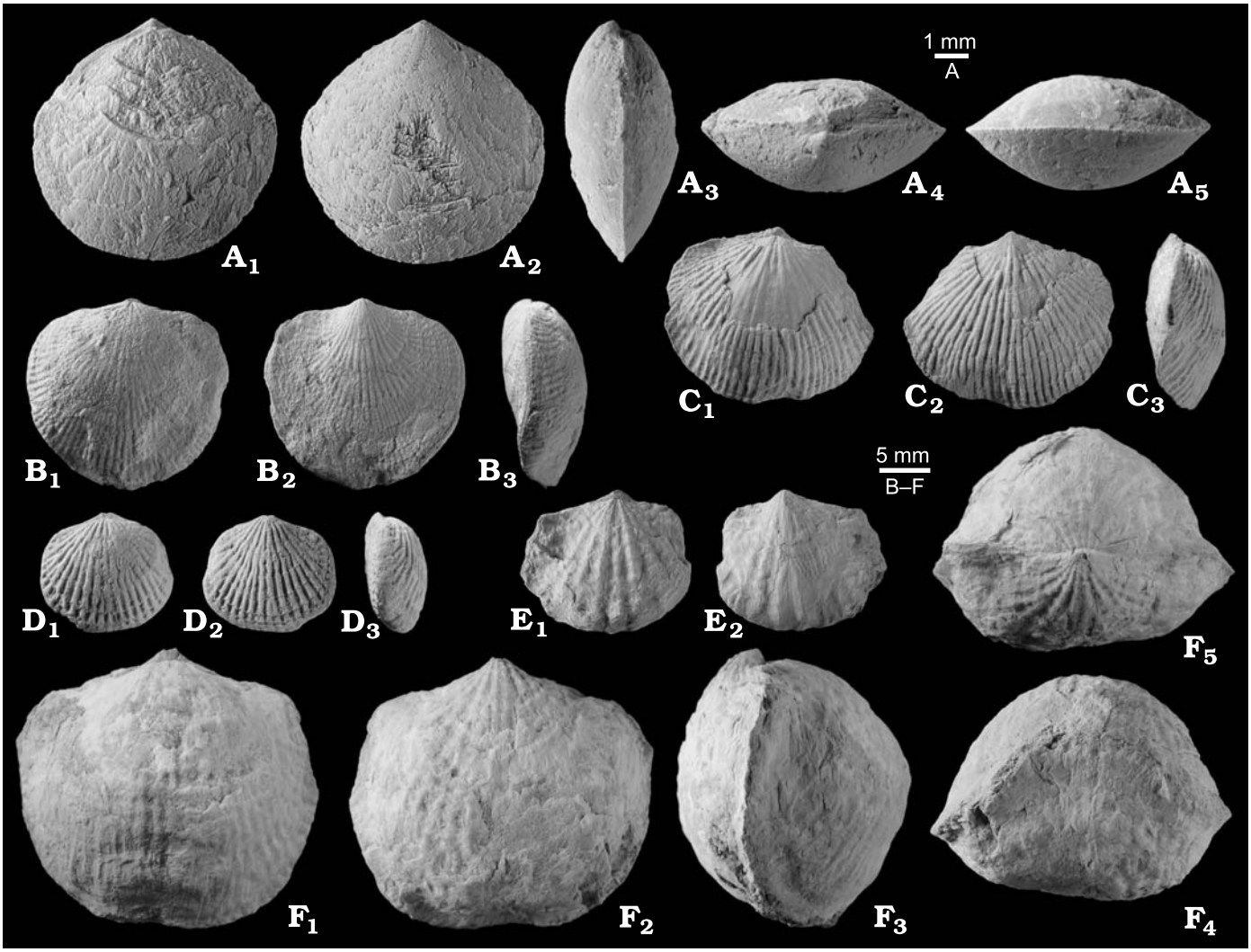

Fig. 18. Athyridid and atrypid brachiopods from the Frasnian of Wietrznia and Dębnik. **A**. *Biernatella lentiformis* Baliński, 1995, ZPAL Bp 60/5, complete shell from the middle Wietrznia Beds of Wietrznia Ie in dorsal (A_1), ventral (A_2), lateral (A_3), posterior (A_4), and anterior (A_5) views. **B**. *Atryparia* (*Costatrypa*) sp., GIUS 4-273 Wt/IM-5, from the middle Wietrznia Beds of Wietrznia Id-W in dorsal (B_1), ventral (B_2), and lateral (B_3) views. **C**, **D**. *Spinatrypina* (*Exatrypa*) cf. *explanata* (Schlotheim, 1820) GIUS 4-273 Wt/IM-10 (**C**) and GIUS 4-273 Wt/IM-13 (**D**) from the middle Wietrznia Beds of Wietrznia Id-W, in dorsal (C_1, D_1), ventral (C_2, D_2), and lateral (C_3, D_3) views. **E**, **F**. *Spinatrypa semilukiana* Ljaschenko, 1959 from the Nodular Limestone (*Palmatolepis hassi* Zone) of Dębnik. **E**. Shell ZPAL Bp 60/20 in dorsal (E_1) and ventral (E_2) views. **F**. Complete shell ZPAL Bp 60/8 in dorsal (F_1), ventral (F_2), lateral (F_3), posterior (F_4), and anterior (F_5) views.

gin suggest, that specimens from Wietrznia are close to *Spinatrypina* (*Exatrypa*) *explanata* (Schlotheim, 1820) from Early Frasnian of Germany (see Copper 1967).

Occurrence.—The species were recovered in the lower part of set C at Wietrznia Id-W and Ie sections representing *Palmatolepis transitans* conodont Zone (Figs. 2, 3).

Genus *Spinatrypa* Stainbrook, 1951

Type species: *Atrypa hystrix* var. *occidentalis* Hall, 1858; Frasnian, Iowa.

Spinatrypa semilukiana Ljaschenko, 1959

Fig. 18E, F.

1959 *Spinatrypa semilukiana* Ljaschenko; Ljaschenko 1959: 174, pl. 51: 1–2; pl. 55: 1v; pl. 56: 1g.

1979 *Spinatrypa semilukiana* Ljaschenko, 1959; Baliński 1979: 60–61, pl. 13: 5, 7–10; pl. 14: 6.

Material.—Five complete shells and two fragments from northern quarry at Dębnik in addition to the collection described earlier from the same locality (see Baliński 1979).

Remarks.—This species was described from the Dębnik anticline by Baliński (1979).

Occurrence.—*Spinatrypa semilukiana* occurs in the Middle Frasnian of the East European Platform (Ljaschenko 1959). The present collection comes from the quarry mentioned above (bed 49 and loose block). Earlier the species was recovered by Baliński (1979) in the Old Tumidalski's quarry and in loose blocks near the northern quarry at village of Dębnik (*Cyrtospirifer bisellatus* local brachiopod Zone).

Order Athyridida Boucot, Johnson, and Staton, 1964
Suborder Athyrididina Johnson and Staton, 1964
Superfamily Athyridoidea Davidson, 1881
Family Athyrididae Davidson, 1881
Subfamiy Helenathyridinae Dagys, 1974
Genus *Biernatella* Baliński, 1977

Type species: *Biernatella polonica* Baliński, 1977; Frasnian, southern Poland.

Biernatella lentiformis Baliński, 1995b

Fig. 18A.

1995 *Biernatella lentiformis* sp. n.; Baliński 1995b: 142–144, figs. 8A–C, 9–11.

2003 *Biernatella lentiformis* Baliński, 1995b; Baliński in Baliński et al. 2003: 221, pl. 157: 2.

Material.—Seventeen complete shells and 35 fragments of shells and single valves were recently found (beds 29–30, 48, 60, 66, 90, 92, 169, and 171 of Wietrznia Ie section) in addition to the material described earlier from the section (Baliński 1995b: 144). Nine specimens were recovered from loose blocks found to the west and east of Wietrznia Id-W section.

Remarks.—This species was described in details by Baliński (1995b) from several localities in the Holy Cross Mountains including the Wietrznia quarry.

Occurrence.—*Biernatella lentiformis* was recovered in several layers in section Id-W and in vicinity of the section Ie of the Wietrznia quarry. It is very common at Józefka near Górno (type locality) where it occurs in detrital and marly limestones of early part of the Frasnian (*Palmatolepis transitans* to *Pa. punctata* zones). It was also found at Czarnów and Dębska Wola; some uncommon and poorly preserved specimens were recovered from Kowala, Jaźwica, and Grabina quarries (Baliński 1995b: 144, fig. 3).

Order Spiriferida Waagen, 1883
Suborder Spiriferidina Waagen, 1883
Superfamily Cyrtospiriferoidea Termier and Termier, 1949
Family Cyrtospiriferidae Termier and Termier, 1949
Subfamily Cyrtospiriferinae Termier and Termier, 1949
Genus *Cyrtospirifer* Nalivkin in Frederiks, 1929

Type species: Spirifer verneuili Murchison, 1840; Frasnian, Belgium.

Cyrtospirifer bisellatus (Gürich, 1903)

Fig. 20F, G.

1903 *Spirifer Archiaci* Murch. var. *bisellata* Gür.; Gürich 1903: 141–142, pl. 1: 1–2.

1979 *Cyrtospirifer bisellatus* (Gürich, 1903); Baliński 1979: 65–66, pl. 16: 1–6; fig. 21.

Material.—One complete shell and seven fragments of disarticulated valves have been recently recovered from the northern quarry near Dębnik (southern Poland).

Remarks.—This species was revised and described in details by Baliński (1979).

Occurrence.—*Cyrtospirifer bisellatus* is a characteristic element of the brachiopod fauna from the highest beds of the northern quarry near village of Dębnik. It is the oldest representative of the genus in the Upper Devonian strata of the Dębnik anticline and an index species of *C. bisellatus* local brachiopod Zone (see Baliński 1979).

Genus *Tenticospirifer* Tien, 1938

Type species: *Spirifer tenticulum* De Verneuil, 1845; Frasnian, Russia.

Tenticospirifer? sp.

Fig. 20C, D.

Material.—Seven fragments of disarticulated valves from Wietrznia Ie section (beds 90 and 92).

Remarks.—This is the only representative of the cyrtospiriferid brachiopods found in the Wietrznia quarry. The specimens, which are very fragmentarily preserved, were attributed to the genus on the basis of high and flat ventral interarea and well marked dorsal fold and ventral sulcus which start from the beaks (see Ma and Day 2000).

Occurrence.—This uncommon species was recovered from set C of Wietrznia Ie section.

Superfamily Ambocoelioidea George, 1931
Family Ambocoeliidae George, 1931
Subfamily Rhynchospiriferinae Paulus, 1957
Genus *Emanuella* Grabau, 1923

Type species: *Nucleospira takwanensis* Kayser, 1883; Middle Devonian, China.

Emanuella sp.

Fig. 20A.

Material.—Two incomplete shells and 13 fragments from Wietrznia Ie section (beds 44–45, 48, 60, 65, 66, and 169).

Remarks.—This uncommon species is characterised by ventribiconvex shell which does not exceeds 16 mm in width and possesses subtrapezoidal outline. Both valves have very faint median furrow or sulcus, which on dorsal valve seems to be slightly stronger. Externally the species resembles somewhat *Emanuella*? sp. from the Middle Devonian (Givetian) of Bathurst Island, Arctic Canada (Johnson and Pery 1976).

Occurrence.—This species was recovered from set C of Wietrznia Ie section representing *Palmatolepis transitans* conodont Zone.

Suborder Delthyridina Ivanova, 1972
Superfamily Delthyrioidea Phillips, 1841
Family Mucrospiriferidae Boucot, 1959
Subfamily Mucrospiriferinae Boucot, 1959

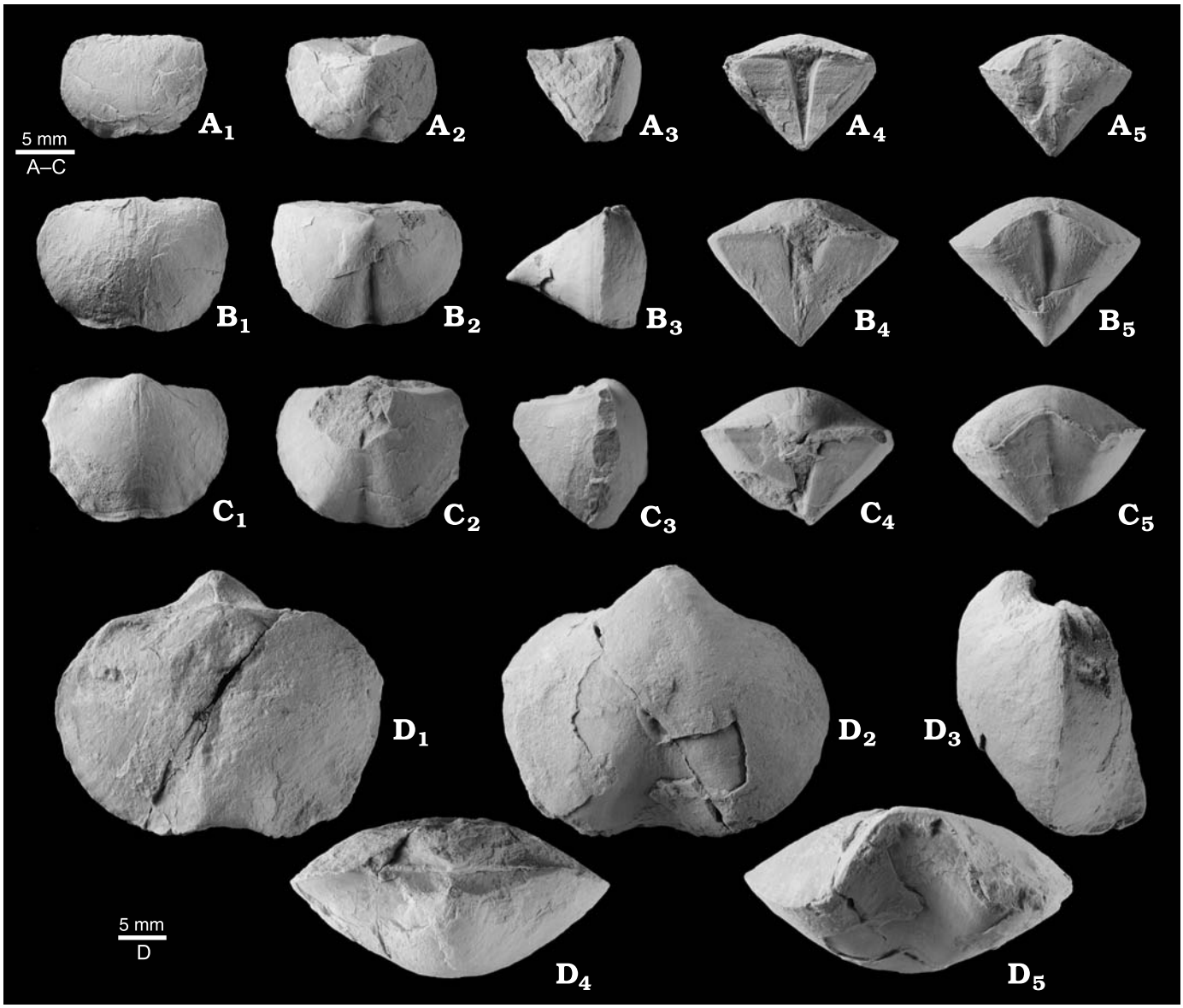

Fig. 19. Spiriferid brachiopods from the Frasnian of Wietrznia and Dębnik. **A**, **B**. *Thomasaria ventosa* sp. nov., ZPAL Bp 60/10 (**A**) and GIUS 4-273 Wt/IM-3 (**B**), two complete shells (**A**—holotype) from the middle Wietrznia Beds of Wietrznia Ie (A) and Id-W (B) in dorsal (A_1, B_1), ventral (A_2, B_2), lateral (A_3, B_3), posterior (A_4, B_4), and anterior (A_5, B_5) views. **C**. *Thomasaria* sp., ZPAL Bp 60/16, incomplete shell from the Nodular Limestone (*Palmatolepis hassi* Zone) of Dębnik in dorsal (C_1), ventral (C_2), lateral (C_3), posterior (C_4), and anterior (C_5) views. **D**. *Warrenella (Warrenella) euryglossa* (Schnur, 1951), ZPAL Bp 60/6, slightly damaged shell from the middle Wietrznia Beds of Wietrznia Ie in dorsal (D_1), ventral (D_2), lateral (D_3), posterior (D_4), and anterior (D_5) views.

Genus *Eleutherokomma* Crickmay, 1950

Type species: *Eleutherokomma hamiltoni* Crickmay, 1950; Waterways Formation, Alberta.

Eleutherokomma zarecznyi (Gürich, 1903)

Fig. 20B.

1903 *Spirifer Zarecznyi.* Var. *angustior.*; Gürich 1903: 139, fig. 1.
1903 *Spirifer Zarecznyi.* Var. *latior.*; Gürich 1903: 139–140, fig. 2.
1979 *Eleutherokomma zarecznyi* (Gürich, 1903); Baliński 1979: 63–64, pl. 15: 1–10.

Material.—One complete shell illustrated here in addition to the collection described earlier (see Baliński 1979).

Remarks.—This species was revised and described in details by Baliński (1979).

Occurrence.—The species is known only from the Dębnik anticline. It is a characteristic element of the brachiopod fauna from the highest beds of the northern quarry near village of Dębnik where it occurs together with *Cyrtospirifer bisellatus* (*C. bisellatus* local brachiopod Zone; see Baliński 1979).

Superfamily Reticularioidea Waagen, 1883
Family Reticulariidae Waagen, 1883
Subfamily Rhenothyridinae Gourvennec, 1994 in Carter et al. 1994

Genus *Warrenella* Crickmay, 1953

Subgenus *Warrenella* (*Warrenella*) Crickmay, 1953

Type species: *Spirifer euryglossus* Schnur, 1851; Frasnian, Germany.

Warrenella (*Warrenella*) *euryglossa* (Schnur, 1851)

Fig. 19D.

1953 *Spirifer euryglossus* m.; Schnur 1953: 209–210, pl. 36: 5.
1957 *Minatothyris euryglossa* (Schnur); Vandercammen 1957: 178–186, pl. 1: 1–22, pl. 2: 1–17, pl. 3: 1–14, figs. 1–6.
1971 *Warrenella euryglossa* (Schnur); Biernat 1971: 156, pl. 7: 1–5, pl. 8: 5–7, fig. 11.
1979 *Warrenella euryglossa* (Schnur, 1951); Baliński 1979: 72–73, pl. 18: 9–10.
1982 *Warrenella euryglossa* (Schnur); Drot 1982: 77, pl. 2: 16.

Material.—One nearly complete shell and one ventral valve from beds 29–30, three specimens from bed 43, one fragment of ventral valve from beds 50–51, and another fragment from bed 60 of Wietrznia Ie section, as well as one incomplete shell from bed 4, one complete shell from bed 14, and single fragment of ventral valve from bed 18 of Wietrznia Id-W section.

Remarks.—Specimens from the Wietrznia quarry are identical in external morphology with *Warrenella* (*W.*) *euryglossa* (Schnur, 1851) from Germany and Belgium.

Occurrence.—*Warrenella* (*W.*) *euryglossa* is known from the Frasnian of Germany and Belgium (Schnur 1853; Vandercammen 1957; Drot 1982). In Poland it was described from the Grained Limestone (*Polygnathus assymmetricus* and probably *Ancyrognathus triangularis* zones) of the Dębnik anticline (southern Poland; Baliński 1979), the Kadzielnia Limestone of Kadzielnia quarry at Kielce (Biernat 1974). Racki (1993b) illustrated one specimen of *W.* cf. *euryglossa* (Schnur, 1851) from the Frasnian upper Sitkówka Beds of Sitkówka, Holy Cross Mountains. The specimens studied here were found in Wietrznia Id-W and Ie sections (*Palmatolepis transitans* Zone).

Family Thomasariidae Cooper and Dutro, 1982

Genus *Thomasaria* Stainbrook, 1945

Type species: *Thomasaria altumbona* Stainbrook, 1945; Frasnian, Iowa.

Thomasaria ventosa sp. nov.

Fig. 19A, B.

Holotype: Complete shell ZPAL Bp 60/10 (Fig. 19A).

Type horizon: Complex C, layer 60, *Palmatolepis transitans* conodont Zone.

Type locality: Wietrznia Ie quarry, SE part of city of Kielce; N 50° 51'21.0'', E 20°38'30.6''.

Derivation of the name: From Latin *ventosus*—windy, to indicate that the material was collected at Wietrznia hill, which name suggests prevailing windy weather condition.

Diagnosis.—About medium-sized for the genus, wider than long, with rounded cardinal extremities; strongly semipyramidal ventral valve, slightly concave to slightly arched in lateral profile; very high, usually flat procline ventral interarea; without fold and radial ribs, wide sulcus with median furrow. From *Thomasaria warreni* Cooper and Dutro, 1982 differs by having much higher and mostly flat ventral interarea. From *T. demissa* Cooper and Dutro, 1982 it is much wider. *T. rockymontana* (Warren, 1928) and *T. altumbona* Stainbrook, 1945 have stronger dorsal fold and radial ribs.

Material.—Wietrznia Id-W: one complete shell and two fragments from bed 4a, two incomplete ventral valves from bed 4g. Wietrznia Ie: three ventral valves embedded in rock from beds 29–30, one complete shell from bed 60, one ventral valve from bed 66, and one incomplete ventral valve from bed 90.

Description.—Shell medium sized for the genus, wider than long, transversely elliptical, strongly ventribiconvex; anterior commissure uniplicate, anterior margin slightly emarginate, both valves smooth without perceptible ribs; hinge margin straight and wide, slightly narrower than maximum shell width, lateral margins rounded, cardinal extremities rounded to angular.

Ventral valve semipyramidal, usually straight to concave, rarely very slightly convex in lateral profile, with convex flanks transversally but straight to slightly concave longitudinally; interarea very long, procline, flat to rarely slightly concave, may be convex in its apical part, its lateral borders form an angle 40–85°; delthyrium narrow, attaining 13–20°; sulcus arises on the umbo, rather shallow but deepened medially with a furrow, wide, occupying 58–62% of the shell width, poorly bounded laterally except at the anterior margin where slightly angular sulcus borders are marked; beak sharply pointed, slightly asymmetrical apically, frequently slightly deflected anteriorly.

Dorsal valve shallow and gently convex; fold imperceptible but the median sector of the valve somewhat deflected close to the margin, suggesting inception of the fold.

Interior of the ventral valve with strong highly divergent dental palates. Apical part of the delthyrium covered by a pair of apical plates. Deltidial plates may also be developed in anterior half of the delthyrium. Shell substance impunctate.

Pustulose microornamentation preserved on one specimen only.

Intraspecific variability.—The specimens here studied display great variability in general shape of the shell as well as in development of the ventral interarea. This condition seems to be characteristic for species of the genus (Davidson 1864–1865; Crickmay 1967; Baliński 1979; Cooper and Dutro 1982). Some of the specimens from beds 29–30 of Wietrznia Ie section have strongly flattened, triangular flanks and median sector of the ventral valve which in combination with high, flat interarea give the valve almost regular shape of a prism with rectangular base. Highly variable is also shape of the ventral interarea expressed in an angle formed by its lateral borders. Among three ventral valves from the beds 29–30 the angle varies from 40 to 78°. The highest measured value of the angle is 85° attained by the specimen from bed 4 of Wietrznia Id-W section.

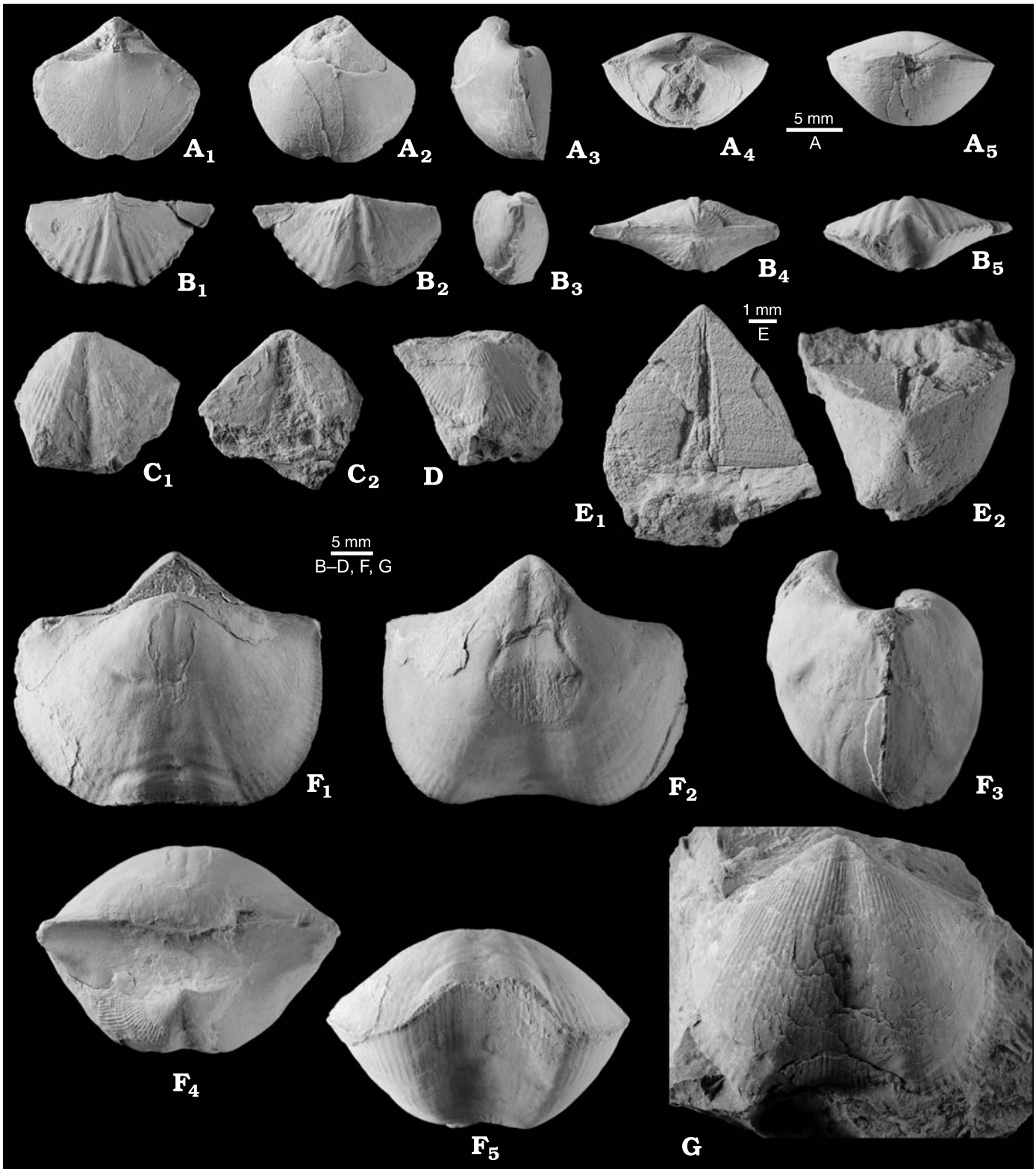

Fig. 20. Spiriferid and spiriferinid brachiopods from the Frasnian of Wietrznia and Dębnik. **A**. *Emanuella* sp., ZPAL Bp 60/20, damaged shell from the middle Wietrznia Beds of Wietrznia Ie in dorsal (A_1), ventral (A_2), lateral (A_3), posterior (A_4), and anterior (A_5) views. **B**. *Eleutherokomma zarecznyi* (Gürich, 1903), ZPAL Bp 60/9, incomplete shell from the Nodular Limestone (*Pa. hassi* Zone) of Dębnik in dorsal (B_1), ventral (B_2), lateral (B_3), posterior (B_4), and anterior (B_5) views. **C**, **D**. *Tenticospirifer*? sp. from the middle Wietrznia Beds of Wietrznia Ie. **C**. Damaged ventral valve ZPAL Bp 60/24 in ventral (C_1) and posterior (C_2) views. **D**. Exterior of incomplete dorsal valve ZPAL Bp 60/25. **E**. *Squamulariina*? sp., GIUS 4-273 Wt/IM-6, ventral valve from the middle Wietrznia Beds of Wietrznia Id-W in posterior (E_1) and ventral (E_2) views. **F**, **G**. *Cyrtospirifer bisellatus* (Gürich, 1903) from the Nodular Limestone (*Palmatolepis hassi* Zone) of Dębnik. **F**. Shell ZPAL Bp 60/14 in dorsal (F_1), ventral (F_2), lateral (F_3), posterior (F_4), and anterior (F_5) views. **G**. Exterior of large ventral valve ZPAL Bp 60/22.

Remarks.—This species differs externally from *Spirifera simplex* Phillips, 1841 from the British Devonian by shell dimensions mainly attaining one third of the shell width of the latter. The Polish specimens also possess wider ventral sulcus deepened medially with longitudinal furrow. Nalivkin (1947) erected genus *Pyramidalia* with *S. simplex* as a type species. The genus was put in synonymy with *Squamulariina* Frederiks, 1916 by Carter et al. (1994) implying possession of spondylium and punctate shell in Phillips' (1841) species. This, however, seems doubtful as Nalivkin (1947: 124) mentioned the presence of dental plates in *Pyramidalia simplex*. Thus, if the presence of dental plates and impunctate shell in type specimens of *Spirifera simplex* will be acknowledged, then the species may belong more probably to *Thomasaria* instead (Baliński 1979).

The most similar species to the new one here described are: *Thomasaria rockymontana* (Warren, 1928), *T. altumona* Stainbrook, 1945, *T. demissa* Cooper and Dutro, 1982, and *T. warreni* Cooper and Dutro, 1982, all from the Frasnian of North America. The new species differs from *T. warreni* by having much higher and most often flat, not concave ventral interarea and flat ventral valve in lateral view which in the latter is quite strongly arched. *T. demissa* is much wider than *T. ventosa* sp. nov. and has generally pointed cardinal extremities. *T. rockymontana* and *T. altumbona* possess better expressed dorsal fold and radial ribs as well as arched ventral valve in lateral profile. The specimens from the Frasnian of the Dębnik anticline (southern Poland) described as *T. simplex* by Baliński (1979) are quite similar to the new species but differ by having better marked radial ribs and usually slightly concave ventral interarea (Fig. 19C).

Occurrence.—This is uncommon species in the Frasnian brachiopod fauna from Wietrznia quarry; it was recovered in Id-W and Ie sections (Figs. 2, 3). One incomplete shell recently recovered from the top-most layers of the northern quarry at Dębnik (southern Poland) is illustrated here as *Thomasaria* sp. for comparison (Fig. 19C).

Order Spiriferinida Ivanova, 1972
Suborder Cyrtinidina Carter and Johnson, 1994 in Carter et al. 1994
Superfamily Cyrtinoidea Frederiks, 1911
Family Cyrtinidae Frederiks, 1911
Genus *Squamulariina* Frederiks, 1916

Type species: *Cyrtina parva* Gürich, 1896; Early Givetian, central Poland.

Squamulariina? sp.

Fig. 20E.

Material.—One slightly damaged ventral valve from Wietrznia Id-W section (bed 4g).

Remarks.—A single ventral valve is referred to the genus on the basis of its hemipyramidal shape, smooth external surface, very high and flat interarea, presence of trichorinum in the apical part of the delthyrium and punctate shell substance. The valve is widest along hinge line where it attains 7.4 mm; interarea is 5.9 mm high. Flanks of the valve are almost flat and triangular, sulcus is shallow and quite narrow. The specimen differs from the type species of the genus *Squamulariina parva* (Gürich, 1896) described from the Middle Devonian of the Holy Cross Mountains, by having much wider and flat, not concave interarea.

Occurrence.—The genus *Squamulariina* is known from the Middle Devonian of Europe, Russia, and China (Gürich 1896; Biernat 1966; Ivanova 1962; Zhang 1989). In Poland it was recovered from the Late Eifelian–Early Givetian strata of Łysogóry region (Halamski 2004). A single specimen described here was found in *Palmatolepis transitans* Zone and may thus represent the youngest occurrence of the genus. However, better collection is needed to acknowledge the upper (Early Frasnian) range of *Squamulariina*.

Summary and conclusions

The paper deals with brachiopod faunas from the Early–Middle Frasnian transition beds from Dębnik (Silesian-Cracow Upland), Wietrznia and Kostomłoty (Holy Cross Mountains) along the South Polish carbonate shelf (part of the southern Laurussian carbonate shelf). The Dębnik strata represent the most proximal part of the pericratonic basin located near the emergent and tectonically stable Sub-Carpathian Arch (Narkiewicz 1985, 1988). The latest Givetian sequence in the area is marked by drowning and elimination of coral-stromatoporoid biostromes and indicated by increase in clastic mud content and evidence for dysaerobic condition with short episodes of improved water circulation. A major transgression during the *Palmatolepis transitans* Zone brought more diversified brachiopod fauna of *Cyrtospirifer bisellatus* assemblage, succeeded by the first rhynchonellids in the topmost layers of the section at Dębnik's northern quarry during the latest part of *Pa. punctata* Zone. The brachiopod fauna is most diverse in this interval and in some layers quite abundant representing the *Plionoptycherhynchus cracoviensis* assemblage.

The $\delta^{13}C$ record at Dębnik's section (see details in Pisarzowska et al. 2006) shows a major positive excursion of ca. 4‰ in the uppermost *Pa. transitans–Pa. punctata* zones and a final gradual decrease in the uppermost part of the section. Sporadic occurrence of brachiopods in the section does not allow detailed study of the biotic response to this geochemical anomaly, although higher brachiopod frequency in the topmost part of the section coincides with gradual decrease of $\delta^{13}C$ and return to the Frasnian background values.

Brachiopods from Wietrznia are more numerous and diversified especially in the lower half of the *Pa. transitans* Zone. They make up a rhynchonellid-dominated fauna assigned here to the *Flabellulirostrum–Coeloterorhynchus* assemblage. Most of the brachiopods of the assemblage were pediculate and attached to hard substrates and some species appear to have been liberosessile as adults.

The carbon isotope record at Wietrznia shows that during the most of *Palmatolepis transitans* Zone the $\delta^{13}C$ values oscillate near Frasnian background values but increase in the interval of the *Pa. punctata* Zone to nearly 4‰ (Pisarzowska et al. 2006; Figs. 2–4). Brachiopods from the *Pa. punctata* Zone are not known except its lowest part where they occur in reworked shell beds (*Biernatella lentiformis* assemblage, Fig. 4). The impoverishment and disappearance of the benthic brachiopod fauna coincides with the observed deepening event and transgressive pulse in the *Pa. punctata* Zone (Middlesex event; see House 2002) and development of severe environmental stresses caused probably by periods with oxygen- and nutrient-deficient conditions in the basin.

In Kostomłoty nearly all brachiopod samples are assignable to the monospecific to low diversity rhynchonellid-dominated *Phlogoiderhynchus polonicus* assemblage that inhabited a muddy substrates of the deeper-water regions of the intrashelf oxygen-depleted basins of Łysogóry-Kostomłoty region (Sartenaer and Racki 1992; Racki et al. 2004). Of special interest is occurrence of discinoid *Romerella*? sp. which frequently colonised large shells of *P. polonicus* because of deficiency of hard substrate suitable for attachment in the predominately muddy bottoms of this region.

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References

Algeo, T.J., Berner, R.A., Maynard, J.B., and Scheckler, S.E. 1995. Late Devonian oceanic anoxic events and biotic crises: "rooted" in the evolution of vascular land plants? *GSA Today* 5: 64–66.

Amsden, T.W. 1953. Some notes on the Pentameracea, including a description of one new genus and one new subfamily. *Journal of the Washington Academy of Sciences* 43: 137–147.

Bai, S.L., Bai, Z.Q., Ma, X.P., Wang, D.R., and Sun, Y.L. 1994. *Devonian Events and Biostratigraphy of South China*. 303 pp. Peking University Press, Beijing.

Baliński, A. 1977. *Biernatella*—a new Devonian double-spired brachiopod. *Acta Palaeontologica Polonica* 22: 175–186.

Baliński, A. 1979. Brachiopods and conodonts from the Frasnian of the Dębnik anticline, southern Poland. *Palaeontologia Polonica* 39: 1–95.

Baliński, 1985. Shell color pattern in an Upper Devonian rhynchonellid brachiopod. *Acta Palaeontologica Polonica* 30: 241–244.

Baliński, A. 1995a. Brachiopods and conodont biostratigraphy of the Famennian from the Dębnik Anticline, southern Poland. *Palaeontologia Polonica* 54: 1–85.

Baliński, A. 1995b. Devonian athyridoid brachiopods with double spiralia. *Acta Palaeontologica Polonica* 40: 129–148.

Baliński, A. Biernat, G., and Studencka, J. 2003. Typ Brachiopoda. *In*: L. Malinowska (ed.), *Budowa geologiczna Polski, tom III, Atlas skamieniałości przewodnich i charakterystycznych, część 1b, z. 1–2, Dewon*, 189–234. Państwowy Instytut Geologiczny, Warszawa.

Biernat, G. 1966. Middle Devonian brachiopods of the Bodzentyn Syncline (Holy Cross Mountains, Poland). *Palaeontologia Polonica* 17: 1–162.

Biernat, G. 1969. On the Frasnian brachiopod genus *Fitzroyella* Veevers from Poland. *Acta Palaeontologica Polonica* 14: 133–155.

Biernat, G. 1971. The brachiopods from the Kadzielnia Limestone (Frasnian) of the Holy Cross Mts. *Acta Geologica Polonica* 21: 137–163.

Biernat, G. and Szulczewski, M. 1975. The Devonian brachiopod *Phlogoiderhynchus polonicus* (Roemer, 1866) from the Holy Cross Mountains, Poland. *Acta Palaeontologica Polonica* 20: 200–221.

Boucot, A.J. 1959. Brachiopods of the Lower Devonian rocks at Highland mills, New York. *Journal of Paleontology* 33: 727–769.

Boucot, A.J., Johnson, J.G., and Staton, R.D. 1964. On some atrypoid, retzioid, and athyridoid Brachiopoda. *Journal of Paleontology* 38: 805–822.

Brice, D. 1971. Étude paléontologique et stratigraphique du Dévonien de l'Afghanistan: Contribution a la connaissance des brachiopodes et des polypiers rugueux. *Notes et Mémoires sur le Moyen-Orient* 11: 1–364.

Brice, D. 1981. Nouvelles observations sur les Orthida et les Rhynchonellida (Brachiopodes) du Frasnien de Ferques (Boulonnais). *Société, Géologique du Nord, Annales* 100: 139–153.

Brice, D. 2000. Rhynchonellida. *In*: P. Bultynck (ed.), Subcommission on Devonian stratigraphy. Fossil groups important for boundary definition. *Courier Forschunginstitut Senckenberg* 220: 66–70.

Brice, D. and Morzadec, P. 1983. Rhynchonellida (Brachiopodes) du Dévonien moyen et supérieur de la Rade de Brest (Massif Armoricain). *Géobios* 16: 549–581.

Bronn, H.G. 1862. *Die Klassen und Ordnungen der Weichthiere (Malacozoa). Vol. 3 (1).* 518 pp. C.F. Winter'sche Verlagshandlung, Leipzig.

Buckman, S.S. 1906. Brachiopod nomenclature: *Epithyris*, *Hypothyris*, *Cleiothyris* Phillips, 1841. *Annals and Magazine of Natural History (series 7)* 16: 321–327.

Budziszewska, E. 1990. *Ramienionogi Pugnacidae (Rhynchonellida) z franu Gór Świętokrzyskich*. 50 pp. M.Sc. thesis, University of Silesia, Sosnowiec.

Carter, J.L, Johnson, J.G., Gourvaennec, R., and Hou, H.-F. 1994. A revised classification of the spiriferid brachiopods. *Annels of Carnegie Museum* 63: 327–374.

Caster, K.E. 1939. A Devonian fauna from Columbia. *Bulletin of American Paleontology* 24: 1–218.

Cherkesova, S.V. [Čerkesova, S.V.] 1973. The vascular system of pentamerids [in Russian]. *Paleontologičeskij žurnal* 1973 (4): 25–34.

Cooper, G.A. and Dutro, J.T. 1982. Devonian brachiopods of New Mexico. *Bulletins of American Paleontology* 82–83: 1–215.

Copper, P. 1966. *Davidsonia* and *Rugodavidsonia* (new genus), cryptic Devonian atrypid brachiopods from Europe and South China. *Journal of Paleontology* 70: 588–602.

Copper, P. 1967. Frasnian Atrypidae (Bergisches Land, Germany). *Palaeontographica A* 126: 116–140.

Copper, P. 1973. New Siluro-Devonian atrypoid brachiopods. *Journal of Paleontology* 47: 484–500.

Copper, P. 1978. Devonian atrypids from western and northern Canada. *Geological Association of Canada Special Paper* 18: 289–331.

Crickmay, C.H. 1950. Some Devonian Spiriferidae from Alberta. *Journal of Paleontology* 24: 210–225.

Crickmay, C.H. 1953. *Warrenella*, a new genus of Devonian brachiopods. *Journal of Paleontology* 27: 596–600.

Crickmay, C.H. 1967. *The Method of Indivisible Aggregates in Studies of the Devonian*. 22 pp. E. de Mille Books, Calgary.

Czarnocki, J. 1948. Przewodnik XX Zjazdu Polskiego Towarzystwa Geologicznego w 1947 r. *Rocznik Polskiego Towarzystwa Geologicznego* 17: 237–299.

Dadlez, R., Kowalczewski, Z., and Znosko, J. 1994. Some key problems of the pre-Permian tectonics of Poland. *Geological Quaterly* 38: 169–190.

Dagys, A.S. Triassic brachiopods (morphology, classification, phylogeny, stratigraphical significance and biogeography) [in Russian]. *Trudy Instituta Geologii i Geofiziki, Akademiâ Nauk SSSR, Sibirskoe Otdelenie* 214: 1–387.

Davidson, T. 1864–1865. A Monograph of the British Fossil Brachiopoda (Vol. 3, Part 6, No. 1: British Devonian Brachiopoda). *Palaeontographical Society (London), Monograph* 16: 1–56.

Davidson, T. 1881. On genera and species of spiral-bearing Brachiopoda, from specimens developed by the Rev. Norman Glass. *Geological Magazine* 8: 1–13.

Drot, J. 1971. Rhynchonellida siluriens et dévoniens du Maroc présaharien. Nouvelles observations. *Service Géologique du Maroc, Notes et Mémoires* 237: 65–108.

Drot, J. 1982. Brachiopods near the Givetian–Frasnian Boundary in Tafilalet and Ma'Der (Southern Morocco). *In*: P. Sartenaer (ed.), *Papers on the Frasnian/Givetian Boundary*, 70-84. International Union of Geological Sciences (IUGS), Subcommission on Carboniferous Stratigraphy, Brussels.

Frederiks, G.N. 1911. Bemerkung über einige Oberpaläeozoische Fosilien von Krasnoufimsk. *Priloženie k protokolam zasedanij Obŝestva Estestvoispytatelej pri Imperatorskom Kazanskom Universitete* 42 (269): 1–11.

Frederiks, G.N. 1916. Paleontological notes. 2. On some upper Paleozoic Brachiopoda of Eurasia [in Russian]. *Trudy Geologičeskogo Komiteta* 156: 1–87.

Frederiks, G.N. 1924. On Upper Carboniferous spiriferids from the Urals [in Russian]. *Izvestiâ Geologičeskogo Komiteta* 38 (1919): 295–324.

George, T.N. 1931. *Ambocoelia* Hall and certain similar British Spiriferidae. *Quarterly Journal of the Geological Society of London* 87: 30–61.

Gill, E.D. 1871. Arrangement of the families of molluscs prepared for the Smithsonian Institution. *Smithsonian Miscellaneous Collections* 227: 1–49.

Głuchowski, E., Casier, J.-G., and Olempska, E. 2006. Crinoid and ostracod succession within the Early–Middle Frasnian interval in the Wietrznia quarry, Holy Cross Mountain, Poland. *Acta Palaeontologica Polonica* 51: 695–706.

Godefroid, J. 1970. Caractéristiques de quelques Atrypids du Dévonien Belge. *Annales de la Société Géologique de Belgique* 93: 87–126.

Godefroid, J. 1998. Le genre *Costatrypa* Copper, 1973 (Brachiopoda, Atrypida) dans le Frasnien du sud de la Belgique. *Bulletin de l'Institut Royal des Sciences Naturelles de Belgique* 68: 97–114.

Godefroid, J. and Racki, G. 1990. Frasnian gypidulid brachiopods from the Holy Cross Mountains (Poland). Comparative stratigraphic analysis with the Dinant Synclinorium (Belgium). *Bulletin de l'Institut Royal des Sciences Naturelles de Belgique* 60: 43–74.

Grabau, A.W. 1923–1924. *Stratigraphy of China, Part 1, Palaeozoic and Older*. 1–200 (1923), 201–528 (1924). China Geological Survey, Beijing.

Gray, J.E. 1840. *Synopsis of the Contents of the British Museum, 42nd edition*. 370 pp. British Museum, London.

Gürich, G. 1896. Das Paläozoicum im Polnischen Mittelgebirge. *Russisch-Kaiserliche Mineralogische Gesellschaft zu St. Petersbourg, Verhandlungen (Ser. 2)* 32: 1–539.

Gürich, G. 1903. Das Devon von Debnik bei Krakau. *Beiträge zur Paläontologie und Geologie Österreich-Ungarns und des Orients* 15: 127–164.

Halamski, A. 2004. *Analiza faunistyczna ramienionogów środkowodewońskich północnej części Gór Świetokrzyskich*. 344 pp. Ph.D. thesis, Instytut Paleobiologii PAN, Warszawa.

Hall, J. 1858. Report on the geological survey of the state of Iowa: embracing the results of investigations made during portions of the years 1855 857. *In*: J. Hall and J.D. Whitney (eds.), *Palaeontology, Vol. 1, Part 2*, 473–724. Published by authority of the legislature of Iowa, Des Moines.

Hall, J. 1867. Descriptions and Figures of Fossil Brachiopoda of the Upper Helderberg, Hamilton, Portage and Chemung Groups. *Palaeontology of New York* 4 (1): 1–428. New York State Geological Survey, Albany.

Hall, J. and Clarke, J.M. 1890. Extract. *Palaeontology of New York* 8 (1): 120–137. Charles van Benthuysen & Sons, Albany.

Havliček, V. 1960. Bericht über die Ergebnisse der Revision der Böhmischen Altpaläozoischen Rhynchonelloidea. *Věstník Ústředního ústavu geologického* 35: 241–244.

Heinke, H.-J. 1978. Ein Weiterer Nachweis von *Fitzroyella* bei Hemer (Ober-Devon; W-Deutschland). *Senckenbergiana lethaea* 59: 367–376.

Hladikova, J., Hladil, J., and Zuskowa, J. 1997. Discrimination between facies and global controls in isotope composition of carbonates: carbon and oxygen isotopes at the Devonian reef margin in Moravia (HV-105 Krtiny borehole). *Journal of the Czech Geological Society* 42: 1–16.

House, M.R. 2002. Strength, timing, setting and cause of mid-Palaeozoic extinctions. *Palaeogeography, Palaeoclimatology, Palaeoecology* 181: 5–25.

Ivanova, E.A. 1962. Ecology and Development of the Silurian and Devonian Brachiopoda of the Kuznetsk, Minussinsk and Tuva Basins [in Russian]. *Akademiia Nauk SSSR, Paleontologičeskij Institut, Trudy* 88: 3–152.

Ivanova, E.A. 1972. Main features of spiriferid evolution (Brachiopoda) [in Russian]. *Paleontologičeskij žurnal* 1972: 28–42.

Johnson, J.G. and Perry, D.G. 1976 Middle Devonian brachiopods from the Bird Fiord Formation of Bathurst Island. *Canadian Journal of Earth Sciences* 13: 615–635.

Kayser, E. 1883. Devonische Versteinerungen aus dem sudwestlichen China. *In*: F.P.W. von Richthofen (ed.), *China, Vol. 4*, 75–102. D. Reimer, Berlin.

King, W. 1846. Remarks on certain genera belonging to the class Palliobranchiata. *Annals and Magazine of Natural History (London), Series 1* 18: 26–42, 83–94.

King, W. 1850. A Monograph of the Permian Fossils of England. *Palaeontographical Society, Monograph* 3: 1–258.

Kuhn, O. 1949. *Lehrbuch der Paläozoologie*. 326 pp. E. Schweizerbart'sche Verlagsbuchhandlung. Stuttgart.

Ljashenko, A.I. [Lâšenko, A.I.] 1973. *Brachiopody i stratygrafiâ nižnefranskih otloženij Ûžnogo Timana i Volgo-Uralskoj neftegazonosnoj provincii.* 280 pp. Nedra, Moskva.

Ma, X. and Day, J. 2000. Revision of *Tenticospirifer* Tien, 1938, and similar spiriferid brachiopod genera from the Late Devonian (Frasnian) of Eurasia, North America, and Australia. *Journal of Paleontology* 74: 444–463.

Maillieux, E. 1909 Note sur les Pentamères frasniens de la bordure méridionale du bassin dinantais. *Bulletin de la Société belge de Géologie, de Paléontologie et d'Hydrologie* 23: 226–234.

Makowski, I. 1988. *Dewońska fauna ramienionogowa z kamieniołomów Wietrznia w Kielcach*. 50 pp. M.Sc. thesis, University of Silesia, Sosnowiec.

Martin, W. 1809. *Petrifacta Derbiensia; or Figures and Descriptions of Petrefactions Collected in Derbyshire*, ix + 28 pp. G. Lyon, Wigan.

McGhee, G.R. 2001. The "multiple impacts hypothesis" for mass extinction: a comparison of the Late Devonian and the late Eocene. *Palaeogeography Palaeoclimatology Palaeoecology* 176: 47–58.

Muir-Wood, H.M. 1955. *A History of the Classification of the Phylum Brachiopoda*. 124 pp. British Museum, London.

Muir-Wood, H.M. and Cooper, G.A. 1960. Morphology, classification and life habits of the Productoidea (Brachiopoda). *Memoir of the Geological Society of America* 81: 1–447.

Nalivkin, D.V. 1941. Brachiopods of the Main Devonian Field [in Russian] *In*: A.A. Borisâk and R.F. Hecker [R.F. Geker] (eds.), *Fauna glavnogo devonskogo polâ, 1*, 139–221. Paleontologičeskij Institut AN SSSR, Moskva.

Nalivkin, D.V. 1947. Class Brachiopoda [in Russian]. *In*: D.V. Nalivkin and

V.N. Verber (eds.), *Atlas rukovodâŝih form iskopaemyh faun SSSR, Vol. 3, Devonskaâ Sistema,* 63–134. VSEGEI-Gosgeoltekhizdat, Leningrad.

Narkiewicz, M. 1985. Badania dewońskiego szelfu węglanowego południowej Polski. *Przegląd Geologiczny* 5: 253–258.

Narkiewicz, M. 1988. Turning points in sedimentary development in the Late Devonian in southern Poland. *In*: N.J. McMillan, A.F. Embry, and A.F. Glass (eds.), Devonian of the World. *Canadian Society of Petroleum Geologists, Memoir* 14: 619–635.

Narkiewicz, M. and Racki, G. 1984. Stratigraphy of the Devonian of the Dębnik anticline. *Kwartalnik Geologiczny* 28: 513–546.

Oehlert, D.P. 1887. Brachiopodes; notions sur l'anatomie et la physiologie des brachiopodes. *In*: P. Fischer (ed.), *Manuel de Conchyliologie et de Paléontologie conchyliologue, ou histoire naturelle des Mollusques vivants et fossiles, Part 11*, 1189–1334. F. Savy, Paris.

Öpik, A.A. 1934. Über Klitamboniten. *Universitatis Tartuensis (Dorpatensis) Acta et Commentationes (series A)* 26: 1–239.

Paulus, B. 1957. *Rhynchospirifer* n. gen. im Rheinischen Devon (Rhynchospiriferinae n. subf., Brachiopoda). *Senckenbergiana lethaea* 38: 49–72.

Phillips, J. 1841. Figures and Descriptions of the Palaeozoic Fossils of Cornwall, Devon, and West Somerset. *Geological Survey of Great Britain, Memoirs* 1: 1–231.

Pisarzowska A., Sobstel, M., and Racki, G. 2006. Conodont-based event stratigraphy of the Early–Middle Frasnian transition on the South Polish carbonate shelf. *Acta Palaeontologica Polonica* 51: 609–646.

Racheboeuf, P.R. 1981. Chonetacés (Brachiopodes) siluriens et dévoniens du Sud-ouest de l'Europe (systématique-phylogénie-biostratigraphie-paléobiogéographie). *Société Géologique et Minéralogique de Bretagne, Mémoires* 27: 1–294.

Racki, G. 1993a. Evolution of the bank to reef complex in the Devonian of the Holy Cross Mountains. *Acta Palaeontologica Polonica* 37 (1992): 87–182.

Racki, G. 1993b. Brachiopod assemblages in the Devonian Kowala Formation of the Holy Cross Mountains. *Acta Palaeontologica Polonica* 37 (for 1992): 297–357.

Racki, G. and Baliński, A. 1981. Environmental interpretation of atrypid shell beds from the Middle to Upper Devonian boundary of the Holy Cross Mountains. *Acta Geologica Polonica* 31: 177–211.

Racki, G. and Baliński, A. 1998. Late Frasnian Atrypida (Brachiopoda) from Poland and Frasnian–Famennian biotic crisis. *Acta Palaeontologica Polonica* 43: 173–304.

Racki, G. and Bultynck, P. 1993. Conodont biostratigraphy of the Middle to Upper Devonian boundary beds in the Kielce area of the Holy Cross Mountains. *Acta Geologica Polonica* 43: 1–33.

Racki, G., Makowski, I., Mikłas, J., and Gawlik, S. 1993. Brachiopod biofacies in the Frasnian reef-complexes: an example from the Holy Cross Mts, Poland. *Prace Naukowe Uniwersytetu Śląskiego* 1331, *Geologia* 12–13: 81–99.

Racki, G., Piechota, A., Bond, D., and Wignall, P.B. 2004. Geochemical and ecological aspects of lower Frasnian pyrite-ammonoid level at Kostomłoty (Holy Cross Mountains, Poland). *Geological Quarterly* 48: 267–282.

Rigaux, E. 1908. *Le Dévonien de Ferques et ses Brachiopodes*. 33 pp. Chez M^{lle} Deligny, Boulogne-sur-Mer.

Roemer, F. 1866. Geognostische Beobachtungen im Polischen Mittergebirge. *Zeitschrift der deutschen geologischen Gesellschaft* 18: 667–690.

Rzhonsnitskaya, M.A. [Ržonsnickaâ, M.A.] 1956. Family Pentameridae and family Camarotoechiidae [in Russian]. *In*: L.L. Khalfin (ed.), *Atlas rukovodâŝih form iskopaemyh fauny i flory zapadnoj Sibiri*, 53–55. Gosgeoltehizdat, Moskva.

Rzhonsnitskaya, M.A. [Ržonsnickaâ, M.A.] 1960. Order Atrypida [in Russian]. *In*: Û.A. Orlov (ed.), *Osnovy paleontologii*; T.G. Saryčeva (asst. ed.), *Vol. 7, Mšanki, brahiopody*, 257–264. Akademia Nauk SSSR, Moskva.

Rzhonsnitskaya, M.A. [Ržonsnickaâ, M.A.] 1964. On Devonian atrypids of the Kuznetsk Basin, paleontology and stratigraphy [in Russian]. *Trudy VSEGEI, Novaâ Seriâ* 93: 91–112.

Rzonsnitzkaya, M.A. [Ržonsnickaâ, M.A.] 1978. A survey of Devonian Rhynchonellida on the outskirts of the Kuznetsk Basin. *Ežegodnik Vsesoûznogo Paleontologičeskogo Obŝestva* 21: 174–196.

Sartenaer, P. 1966. Frasnian Rhynchonellida from the Ozbak-Kuh and Tabas Regions (east Iran). *Geological Survey of Iran, Report* 6: 25-53

Sartenaer, P. 1970. Nouveaux genres Rhynchonellides (Brachiopodes) du Paléozoïque. *Bulletin de l'Institut Royal des Sciences Naturelles de Belgique* 46: 1–32.

Sartenaer, P. 1971. Genres rhynchonellides (brachiopodes) nouveaux. *Bulletin de l'Institut Royal des Sciences Naturelles de Belgique* 47: 1–7.

Sartenaer, P. 1979. Deux nouveaux genres de rhynchonellides Frasniens précédément inclus dans le genre *Calvinaria* (Brachiopoda). *Géobios* 12: 535–547.

Sartenaer, P. 1985. The biostratigraphical significance of rhynchonellid genera at the Givetian–Frasnian boundary. *Courier Forschunginstitut Senckenberg* 75: 311–318.

Sartenaer, P. 2003. *Tullypothyridina*, new late Givetian rhynchonellid brachiopod genus. *Bulletin de l'Institut Royal des Sciences Naturelles de Belgique* 73: 29–51.

Sartenaer, P. and Racki, G. 1992. A new Late Givetian rhynchonellid species from the Holy Cross Mountains, Poland, and its relevance to stratigraphical and ecological problems near the Givetian/Frasnian boundary. *Bulletin de l'Institut Royal des Sciences Naturelles de Belgique* 62: 61–73.

Sarytcheva, T.G. [Saryčeva, T.G.] and Sokolskaya, A.N. [Sokol'skaâ, A.N.] 1959. On classification of pseudopunctate brachiopods [in Russian]. *Doklady Akademii Nauk SSSR* 125: 181–184.

Schieber, J. 2003. Disturbed beds in lower Frasnian black shales of Tennessee and Kentucky: their possible connection to impacts. *Geological Society of America, Abstacts with Pograms* 35: 209.

Schlotheim, E.F. von 1820. *Die Petrefactenkunde auf ihrem jetzigen Standpunkte durch die Beschreibung seiner Sammlung versteinerter und fossiler Überreste des Thier- und Pflanzenreichs der Vorwelt erläutert*. 726 pp. Bekker, Gotha.

Schmidt, H. 1941. Rhynchonellidae aus Rechtsrheinischem Devon. *Senckenbergiana* 23: 277–290.

Schmidt, H. 1975. Septalariinae (Brachiopoda, Rhynchonellida) im Devon westlich und östlich des Rheins. *Senckenbergiana lethaea* 56: 85–121.

Schnur, J. 1953. Zusammenstellung und Beschreibung sämmtlicher im Uebergangsgebirge der Eifel Vorkommenden Brachiopoden nebst Abbildungen derselben. *In*: W. Dunker and H. Von Meyer (eds.), Beiträge zur Naturgeschichte der Vorwelt. *Palaeontographica* 3: 169–248.

Schuchert, C. 1893. Classification of the Brachiopoda. *American Geologist* 11: 141–167.

Schuchert, C. and Cooper, G.A. 1931. Synopsis of the brachiopod genera of the suborders Orthoidea and Pentameroidea, with notes on the Telotremata. *American Journal of Science (series 5)* 22: 241–255.

Schuchert, C. and Cooper, G.A. 1932. Brachiopod genera of the suborders Orthoidea and Pentameroidea. *Peabody Museum of Natural History, Memoirs* 4: 1–270.

Schuchert, C. and LeVene, C.M. 1929. Brachiopoda (generum et genotyporum index et bibliographia). *In*: J.F. Pompeckj (ed.), *Fossilium Catalogus, Vol. I: Animalia, Pars 42*, 1–140. W. Junk, Berlin.

Sowerby, J. de C. 1840. On the physical structure and older stratified deposits of Devonshire. *Transaction of the Geological Society of London (2nd series)* 5: 633–703.

Stainbrook, M.A. 1943. Strophomenacea of the Cedar Valley Limestone of Iowa. *Journal of Paleontology* 17: 39–59.

Stainbrook, M.A. 1945. Brachiopoda of the Independence Shale of Iowa. *Geological Society of America, Memoir* 14: 1–74.

Stainbrook, M.A. 1951. Substitution for the pre-occupied brachiopod name *Hystricina*. *Journal of the Washington Academy of Sciences* 41: 196.

Stehli, F.G. 1954. Lower Leonardian Brachiopoda of the Sierra Diablo. *Bulletin of the American Museum of Natural History* 105: 257–358.

Struve, V. 1978. Beiträge zur Kenntnis devonischer Brachiopoden, 19: Arten von *Fitzroyella* (Rhynchonellida; Givetium und Frasnium von Europa und Australien). *Senckenbergiana lethaea* 59: 329–365.

Szulczewski, M. 1971. Upper Devonian conodonts, stratigraphy and facial development in the Holy Cross Mts. *Acta Geologica Polonica* 21: 1–129.

Szulczewski, M. and Dvořák, J. 1995. Guide to Excursion B4. Evolution of the Polish-Moravian carbonate platform in the Late Devonian and Early Carboniferous: Holy Cross Mts., Kraków Upland, Moravian Karst. *In*: J. Dvořák, A. Galle, H.-G. Herbig, Z. Krejči, J. Malec, M. Paszkowski, G. Racki, S. Skompski, M. Szulczewski, and H. Żakowa (eds.), *XIII International Congress on Carboniferous–Permian (XIII ICC–P)*, 24–26. Państwowy Instytut Geologiczny, Warszawa.

Termier, H. and Termier, G. 1949. Essai sur l'evolution des Spiriférides. *Service Géologique du Maroc, Notes et Mémoires* 74: 85–112.

Tien, C.C. 1938. Devonian Brachiopoda of Hunan. *Palaeontologia Sinica, Ser. B* 4: 1–192.

Vandercammen, A. 1957. Révision des Reticulariinae du Dévonien de la Belgique. 1. Genre *Minatothyris* A. Vandercammen, 1957. *Bulletin de l'Institut Royal des Sciences Naturelles de Belgique* 33: 1–19.

Veevers, J.J. 1959. Devonian Brachiopods from the Fitzroy Basin, Western Australia. *Bureau of Mineral Resources (BMR) Bulletin of Australian Geology and Geophysics* 45: 1–220.

Verneuil, E. de 1845. Paléontologie, mollusques, brachiopodes. *In*: R.I. Murchison, E. de Verneuil, and A. Keyserling (eds.), *Géologie de la Russie d'Europe et des Montagnes de l'Oural. Vol. 2, Part 3: Paléontologie*, 17–395. John Murray, London.

Waagen, W. 1883. Salt Range fossils, Vol. 1, Part 4. *Productus*-Limestone fossils, Brachiopoda. *Memoirs of the Geological Society of India, Palaeontologia Indica (Series 13)* 3–4: 391–546.

Waagen, W. 1884. Salt Range fossils, Vol. 1, Part 4. *Productus*-Limestone fossils, Brachiopoda. *Memoirs of the Geological Society of India, Palaeontologia Indica (Series 13)* 3–4: 547–610.

Waagen, W. 1885. Salt Range fossils, Vol. 1, Part 4. *Productus* Limestone fossils, Brachiopoda. *Memoirs of the Geological Society of India, Palaeontologia Indica (Series 13)* 5: 729–770.

Wang, Y. 1985. Genus Xiaobangdaia. *In*: Y. Jin, Y. Wang, D. Sun, and Q. Shi, *Late Paleozoic and Triassic Brachiopods from the East of the Qinghai-Xizang Plateau. Stratigraphy and Palaeontology in Western Sichuan and Eastern Xizang, China, Part 3*, 182–249. Sichuan Scientific Technical Publishing House, Chengdu.

Warren, P.S. 1928. The Palaeozoics of the Crowsnest Pass, Alberta. *Transactions of the Royal Society of Canada, section 4* 22: 109–119.

Yans, J., Corfield, R.M., Racki, G., and Préat, A. (in press). Evidence for a major perturbation of the carbon cycle in the Middle Frasnian *punctata* conodont Zone. *Geological Magazine*.

Zhang, Y. 1989. Early Middle Devonian Brachiopod Community of *Pseudocamarophoria-Uncinulus* in the Huama Area, West Qinling Ranges of Gansu, China. *Bulletin of the Xian Institute of Geology and Mineral Resources* 26: 93–99.