Crinoid and ostracod succession within the Early–Middle Frasnian interval in the Wietrznia quarry, Holy Cross Mountains, Poland

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Early–Middle Frasnian ostracods and crinoids from Wietrznia in the Northern Kielce subregion of the Holy Cross area were analyzed. Twenty three ostracod species assigned to thirteen named genera, as well as eighteen crinoid species including the representatives of fifteen stem-based taxa were distinguished. For most of the species open nomenclature is applied. The composition of ostracod assemblage changes from moderately diverse in the lower part of the *Palmatolepis transitans* Zone to poorly diverse in its higher part. Lack of ostracods in the uppermost part of the *Pa. transitans* Zone and in the *Palmatolepis punctata* Zone is noted. The crinoid distribution pattern comprises the interval of relatively high diversity, interrupted in the uppermost part of the *Pa. transitans* Zone, and the interval of temporary recovery in the lower *Pa. punctata* Zone. Such distribution patterns point to deterioration of environmental conditions across the Early–Middle Frasnian transition, coinciding with a large-scale C-isotopic perturbation superimposed on intermittent, two-step eustatic sea level rise. On the other hand, impoverished, surviving crinoid faunas and absence of ostracods in the *Pa. punctata* Zone indicate the overall long-term deterioration of life conditions through the major C-isotope anomaly time span. However, this may also result from synsedimentary tectonic pulses, causing block movements and large-scale resedimentation phenomena on the northern slope of the Dyminy Reef during the basal Middle Frasnian sea level rise.

Key words: Crinoidea, Ostracoda, Frasnian, Holy Cross Mountains, Poland.

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Introduction

The crinoids from Early–Middle Frasnian section at Wietrznia are preserved exclusively as disarticulated skeletal elements, particularly stem ossicles, which makes their classification within "natural" system impossible. Therefore, most of the columnals identified here have been classified in the category of subclass and order uncertain, according to the taxonomic concept of Moore and Jeffords (1968). Such procedure has long been used for the stems of Paleozoic crinoids, despite obvious weaknesses and restrictions (for detailed discussion see Moore and Jeffords 1968; Le Menn 1985; Donovan 1986–1995, 2001; Stukalina 1988; Głuchowski 1993, 2002). Frasnian stem-defined crinoid faunas are known from numerous localities in southern Poland (Głuchowski 1993), and also are documented in France (Le Menn 1988), Russia, Kazakhstan and Armenia (Dubatolova 1964, 1971; Yeltyschewa and Stukalina 1977).

Frasnian crinoids from Wietrznia have not been described in detail so far. However, Głuchowski (1981a, b) reported some crinoid taxa from Givetian–Frasnian Lower Wietrznia Beds (*Mesotaxis falsiovalis* and lower part of *Palmatolepis transitans* zones) of this locality. Later, these data were partly verified and completed in the first report on Early Frasnian crinoids from the *Phlogoiderhynchus* Level by Głuchowski (1993). Frasnian ostracods from Wietrznia quarry are reported for the first time. The paper presents the stratigraphic, palaeoenvironmental, and systematic account of Frasnian ostracods and crinoids from this quarry and the results are part of a larger interdisciplinary study on the Early–Middle Frasnian transition interval (see Pisarzowska et al. 2006).

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

Stratigraphical setting

The Wietrznia hill is situated in the Northern Kielce subregion in south-eastern part of Kielce suburbs and belongs to eastern

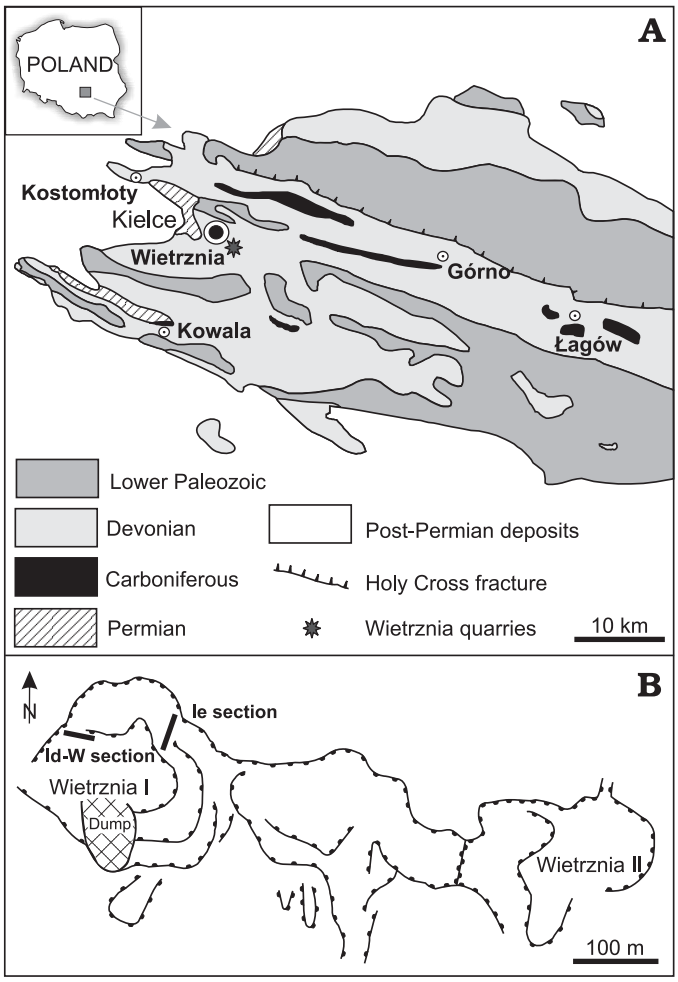

Fig. 1. **A**. Geological map of western part of the Holy Cross Mountains and location of study site (simplified from Marynowski et al. 2000). **B**. Sketch map of Wietrznia quarries and location of the studied sections (modified from Makowski 1993).

part of the Kadzielnia Chain (Fig. 1A). Large exposure on this hill consists of three interconnected inactive quarries: Wietrznia (= Wietrznia I of Szulczewski 1971), Eastern Międzygórz (= Wietrznia II of Szulczewski 1971) and a quarry at Międzygórz situated between them (Fig. 1B). Calcareous-marly deposits from Wietrznia contain a rich and diverse fauna, including stromatoporoids, receptaculitids, rugose corals, tabulate corals, brachiopods, and crinoids. These fossil-rich sediments had been already considered by Gürich (1896: 78) as Middle–Upper Devonian transitional strata (Übergangschichten von Wietrznia), however later, Czarnocki (1948) included the entire sequence in the Frasnian. Szulczewski (1971) interpreted the Frasnian from Wietrznia as developed in transitional facies, comprising both reef-derived and basin deposits, and distinguished several lithological units (referred to as sets A-H). His conodont studies confirmed the Frasnian age of the majority of them. He stated, however, that the lowest part of this section (set A and lower part of set B) may belong to the uppermost Givetian and its highest part (set H) undoubtedly belongs already to the Famennian. Moreover, he concluded that the brachiopod-rich set C documented both in Wietrznia I and Wietrznia II quarries, is contained within the interval corresponding to *Palmatolepis transitans* to *Palmatolepis hassi* zones of the current zonation. Racki (1993) defined the set C as *Phlogoiderhynchus* Marly Level and subdivided the Wietrznia Beds, intertwined with this level into lower (sets A and B) and upper (D and higher sets) ones. Conodont studies of Racki and Bultynck (1993) confirmed the latest Givetian age (*M. falsiovalis* Zone) of the oldest strata of the Wietrznia sections and marked out the Middle–Upper Devonian boundary within set B. Recent conodont studies by Sobstel et al. (2006) and Pisarzowska et al. (2006) for Wietrznia I quarry showed that the Early–Middle Frasnian boundary (*Pa. transitans–Pa. punctata* zones) is in the top of the *Phlogoiderhynchus* Level (set C). Moreover, they defined this set C as middle Wietrznia Beds and the ca. 1.5 m topmost its part as the Śluchowice Marly Level.

Material and methods

The examined paleontological material comes solely from the Wietrznia I quarry (Fig. 1B). Fifteen crinoid bulk samples were collected from section Ie situated in the NE part of the quarry. The total crinoid collection comprises more than fifteen hundred columnals, short pluricolumnals, four small bipyramidal thecae and a few radials and orals of *Haplocrinites*, poorly preserved in the majority. They were obtained mostly from acetic acid residues of limestones. Only some specimens were studied on the weathered rock slab surfaces and rock surfaces etched with acetic acid. The specimens from the weathered rock surfaces were cleaned with an ultrasonic disintegrator.

The examined ostracod material comes from eight bulk rock samples collected from section Id-W situated in the NW part of the quarry. The total ostracod collection comprises about 490 carapaces and their fragments, poorly preserved in the majority. They were extracted from hard limestones using the hot acetolysis method developed by Lethiers and Crasquin-Soleau (1988). Marly sediments macerated in Na_2SO_4, have yielded generally very rare ostracod specimens.

Review of species

Subphyllum Crustacea, Brünnich, 1772
Class Ostracoda Latreille, 1802

***Acratia tichonovitchi* Egorov, 1953** (Fig. 2V).—This species is known from the Frasnian of the Russian Platform (Egorov 1953) and from the Frasnian of Sobiekurów, Holy Cross Mountains (Olempska 1979). It is similar in lateral outline to *Acratia* sp. A *sensu* Malec and Racki (1992) from the Late Givetian of Stokówka (Holy Cross Mountains, Poland).

***Amphissites* sp.** (Fig. 2B).—The species is maybe related to *Amphissites* cf. *parvulus* (Paeckelmann, 1913) known from the middle part of the Frasnian in the Dinant Basin, Belgium (Becker 1971).

***Bairdia* (*Rectobairdia*) *paffrathensis* Kummerow, 1953** (Fig. 2T).—This species is known from the Middle Devonian (Upper Givetian) of Pomerania (Żbikowska 1983) and the Holy Cross Mountains (Olempska 1979); from the Givetian of the Namur Synclinorium, Belgium (Casier and Préat 2006), and Frasnian of the Dinant Basin (Casier 1987).

***Bairdia* sp. A** (Fig. 2R).—*B*. sp. A differs from other species of *Bairdia* in having a ridge subparallel to the dorsal margin.

***Bairdia* sp. B** (Fig. 2S).—This species is similar in the lateral outline to *Bairdia* (*R.*) sp. of Olempska (1979: pl. 18: 6), from the Famennian (do V) of the Holy Cross Mountains.

***Bairdia* sp. C** (Fig. 2U).—*B*. sp. C is similar in its lateral outline to the *Bairdia symmetrica* Egorov, 1953 from the Frasnian of Russian Platform.

***Bairdia* (*Rectobairdia*) sp. nov. A** (Fig. 2O, P).—In lateral outline this new sp. A resembles representatives of the subgenus *Rectobairdia*. *Bairdia* (*R.*) sp. nov. A is distinguishable by the presence of a long ridge skirting the free border from the anterior to the posterior extremities, and by an other subelliptic ridge in the median part of the valves forming a spur. *Bairdia* (*R.*) sp. B of Becker (1971) from the middle part of the Frasnian of the Dinant Basin, Belgium, *Rectobairdia* sp. 14 of Braun (1967) from the upper part of the Frasnian of Alberta, and *Bairdia transverscostata* Rozhdestvenskaja, 1962 are close to *Bairdia* (*R.*) sp. nov. A. However, these three latter species are characterized by the presence of two vertical ridges.

***Bairdiacypris* sp**. (Fig. 2N).—This species is characterized by its slightly concave ventral margin.

***Bairdiocypris* sp. A** (Fig. 2I).—*B*. sp. A is similar in the lateral outline to *Bairdiocypris rhenana* (Kegel, 1932) from the Middle Devonian of Europe.

***Bairdiocypris* sp. B** (Fig. 2J).—This species differs from *B*. sp. A in having a more broadly rounded anterior end and wider carapace.

***Bairdiocypris* sp. C** (Fig. 2K).—This species is similar in the lateral outline to *Bairdiocypris marginata* Adamczak, 1976, from Grzegorzowice Formation, Middle Devonian, Holy Cross Mountains (Adamczak 1976).

***Cytherellina*? sp.** (Fig. 2M).—The genus *Cytherellina* Jones and Holl, 1869, differs from other similar in outline genera, by the presence of internal sulcament (Adamczak 2005).

***Healdianella* cf. *alba* Lethiers, 1981** (Fig. 2L).—This long ranging species has been described from the late Frasnian (doIγ) to the Strunien (do VI) of Alberta, Canada, and also from the late Famennian (Fa2c) of Avesnois, France.

***Hollinella* sp.** (Fig. 2A).—This species is close to *Hollinella* (*Keslingella*) *lionica* Becker and Bless, 1971, described from the Middle Frasnian of the Dinant Basin, Belgium.

***Microcheilinella* sp. A** (Fig. 2G).—It differs from *M*. sp. B in slightly concave ventral margin and wider posterior end of the carapace. Closely related species are known from the Middle–Upper Devonian sections.

***Microcheilinella* sp. B** (Fig. 2H).—*M*. sp. B differs from *M*. sp. A in having a less concave ventral margin and a less wider carapace in the posterior part.

***Micronewsomites* sp.** (Fig. 2F).—Rare small and very gibbose carapaces are reported to the genus *Micronewsomites* in sample Id-W-9.

***Orthocypris* sp.** (Fig. 2W).—It is similar in having a relatively long carapace to *Orthocypris perlonga* Kummerow, 1953 known from the Middle Devonian of Europe.

***Schneideria groosae* Becker, 1971** (Fig. 2X).—This species is known from the Middle Frasnian of Western Pomerania (Żbikowska 1983) and from the Middle Frasnian of the Dinant Basin, Belgium (Becker 1971).

***Scrobicula* sp. aff. *S. capsa* Becker, 1971** (Fig. 2Y).—This taxon of unknown affinities is represented in the Wietrznia section (Id-W-31) by rare specimens.

***Uchtovia* sp.** (Fig. 2D).—This platycopine species is similar to *Uchtovia materni* Becker, 1971 *sensu* Żbikowska (1983). *U. materni* is known from the Middle Frasnian of Western Pomerania (Poland) and of the Dinant and Namur Basins (Belgium). Specimens from Wietrznia differs from the latter in poorly developed two sulci.

Class Crinoidea Miller, 1821
Subclass Camerata Wachsmuth and Springer, 1885
Order Monobathrida Moore and Laudon, 1943
Family Platycrinitidae Austin and Austin, 1842

***Platycrinites* sp.** (Fig. 3A, B).—The columnals are very small, elliptical with straight and smooth latus. The articular facet is commonly smooth and surrounded by a delicate furrow. The fulcrum is lacking or very weakly developed and composed of minute ridges and/or 2–3 marginal culmina on some specimens. The lumen is circular, medium-sized. Generally, the articulum resembles that of *Platycrinites minimalis* Głuchowski, 1980 described from Eifelian–Givetian Skały Beds of the Holy Cross Mountains (Głuchowski 1980), but differs in having somewhat larger lumen and lacking concave bifascial fields.

Subclass Inadunata Wachsmuth and Springer, 1885
Order Disparida Moore and Laudon, 1943
Family Haplocrinitidae Bassler, 1938

***Haplocrinites* sp.** (Fig. 3C, D).—The aboral cup is wide and cupuliform with pentagonal outline in oral view. Radial fac-

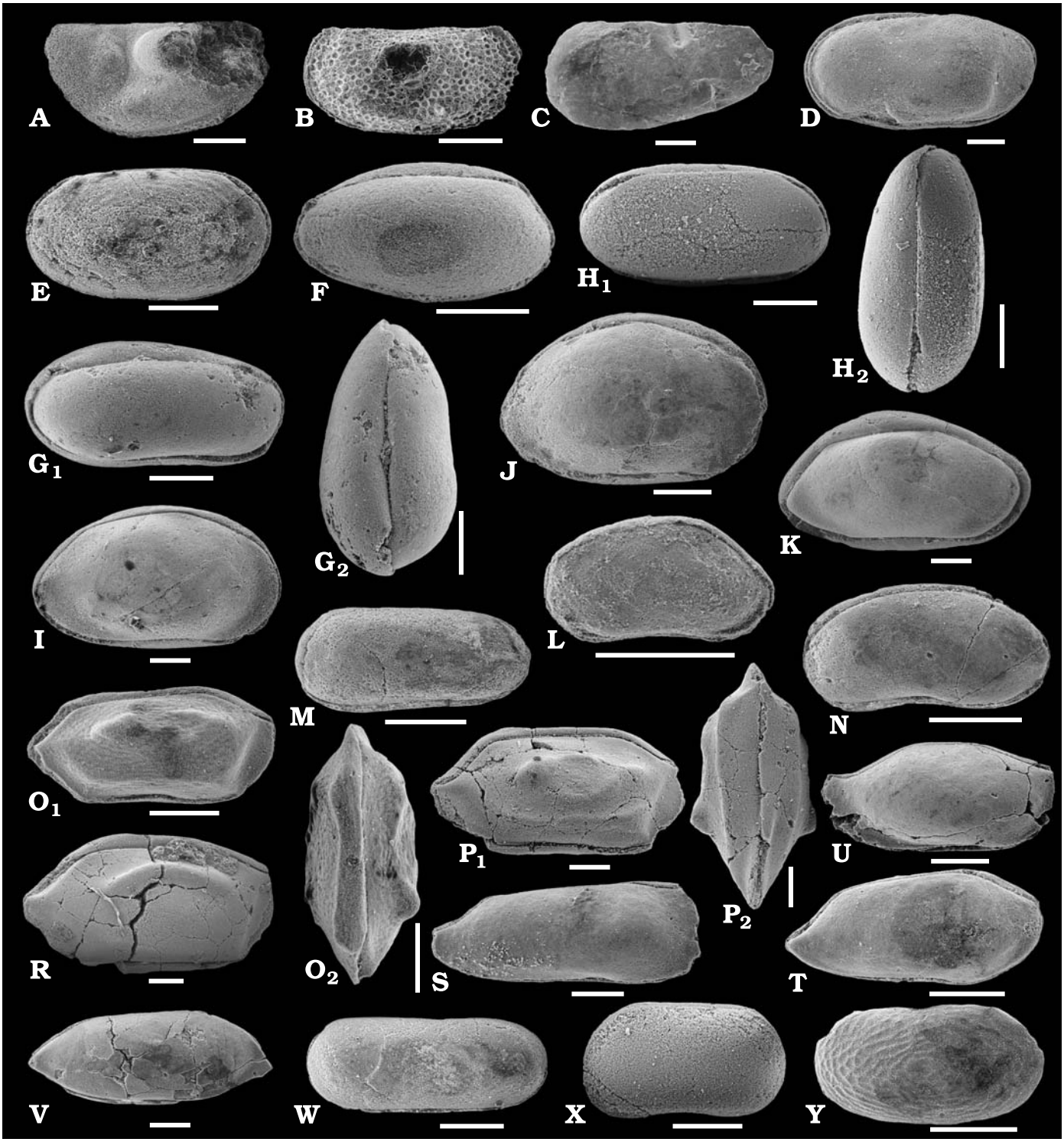

Fig. 2. Early Frasnian (*Palmatolepis transitans* Zone) ostracods from the Wietrznia Id-W section, Holy Cross Mountains. **A**. *Hollinella* sp., ZPAL O.57/1, sample Id-W-29, in left valve in lateral view. **B**. *Amphissites* sp. aff. *A. parvulus* (Paeckelmann, 1913), ZPAL O.57/2, sample Id-W-9, right valve in lateral view. **C**. Palaeocopida indet., ZPAL O.57/3, sample Id-W-39, left valve in lateral view. **D**. *Uchtovia* sp., ZPAL O.57/4, sample Id-W-31, carapace in left lateral view. **E**. Paraparchitidae? sp. indet., ZPAL O.57/5, sample Id-W-31, carapace in right lateral view. **F**. *Micronewsomites* sp., ZPAL O.57/6, sample Id-W-9, carapace in right lateral view. **G**. *Microcheilinella* sp. A., ZPAL O.57/7, sample Id-W-17, carapace in right lateral (G_1) and dorsal (G_2) views. **H**. *Microcheilinella* sp. B, ZPAL O.57/8, sample Id-W-39, carapace in right lateral (H_1) and dorsal (H_2) views. **I**. *Bairdiocypris* sp. A, ZPAL O.57/9, sample Id-W-31, carapace in right lateral view. **J**. *Bairdiocypris* sp. B, ZPAL O.57/10, sample Id-W-31, carapace in right lateral view. **K**. *Bairdiocypris* sp. C, ZPAL O.57/11, sample Id-W-31, carapace in right lateral view. **L**. *Healdianella* cf. *alba* Lethiers, 1981, ZPAL O.57/12, sample Id-W-17, carapace in right lateral view. **M**. *Cytherellina*? sp., ZPAL O.57/13, sample Id-W-31, carapace in right lateral view. **N**. *Bairdiacypris* sp. A, ZPAL O.57/14, sample Id-W-9, carapace in right lateral view. **O**, **P**. *Bairdia* (*Rectobairdia*) sp. nov. A. **O**. ZPAL O. 57/15, sample Id-W-31, carapace in right lateral (O_1) and dorsal (O_2) views. →

ets are narrow, trapezoidal. Oral pyramid is as high as the calyx. The external surface of the oral plates is flat. The thecae are most similar to *Haplocrinites stellaris* (Roemer, 1844) reported from Givetian–Frasnian Red Iron Horizon of the East Sauerland, Germany (Roemer 1844; Sandberger and Sandberger 1850–1856), but differ in having a relatively less elevated oral part. They differ from *Haplocrinites gluchowskii* Hauser, 2002 reported from Late Frasnian Detrital Beds of the Holy Cross Mountains (Głuchowski 1993), Upper Wallersheim Dolomite of the Eifel Mountains, Germany (Hauser 2002) and the Neuville Formation of the Dinant Basin, Belgium (Hauser 2003) in having distinctly less prominent radial facets.

Order Cladida Moore and Laudon, 1943

Family Cupressocrinitidae Roemer, 1854

***Cupressocrinites* sp.** (Fig. 3E).—The columnals are small, rounded triangular with smooth and slightly convex latus. The articular facet is flat and bordered by a narrow crenularium composed of thick culmina. The lumen is large, trilobate with distinct constrictions in the middle part of the lobes. The columnals are similar to those of Givetian *Cupressocrinites inflatus* Schultze, 1867 reported from the Loogh Formation of the Eifel Mountains, Germany (Schultze 1867), and the Portilla Formation of León, Spain (Breimer 1962), Laskowa Góra Beds and Kowala Formation of the Holy Cross Mountains (Głuchowski 1993), as well Givetian *Cupressocrinites sampelayoi* (Almela and Revilla, 1950) reported from the Portilla Formation (Almela and Revilla 1950; Breimer 1962) and Laskowa Góra Beds (Głuchowski 1993), but differ in having more triangular outline and thicker culmina. Le Menn (1988) described similar triangular, rounded columnals with a trilobate axial canal and thin culmina from Frasnian Beaulieu Formation of Boulonnais, France as *Trilobocrinus boloniensis* Le Menn, 1988 but they may belong to *Cupressocrinites*.

Subclass and order uncertain

Family Anthinocrinidae Yeltyschewa and Sisova in Schevtschenko, 1966

***Anthinocrinus wenjukowi* Yeltyschewa in Yeltyschewa and Stukalina, 1977** (Fig. 3G).—The species was first described from Frasnian Tschudov Beds of Novaya Zemlya, Russia (Yeltyschewa and Stukalina 1977) and was also reported from other Early Frasnian localities in the Holy Cross Mountains (see Głuchowski 1993).

***Floricrinus* sp.** (Fig. 3F).—The columnals are pentagonal to rounded pentagonal with smooth latus. The articular facet is flat with very well developed pentalobate areola surrounded by crenularium composed of short, moderately thick culmina. The medial culmina between petals form distinctive pattern of V's or Y's. The petals are drop-like in outline, separated by faint ridges diminishing toward the lumen and composed of very weakly developed adradial crenulae. The lumen is pentagonal, rounded. Generally, the articulum resembles that of *Floricrinus proteus* Stukalina, 1977 described from Pragian Sardzhal Horizon of Northern Pribalkhasch, Kazakhstan (Stukalina 1977), but differs in having very weakly developed crenulae separating the petals.

Family Fluctichara cidae Moore and Jeffords, 1968

***Marettocrinus kartzevae* (Yeltyschewa and Dubatolova in Dubatolova and Yeltyschewa, 1961)** (Fig. 3H).—The species was reported from other Givetian–Frasnian localities in the Holy Cross Mountains, as well as the Early Frasnian of the Sudetes (see Głuchowski 1993). Moreover, it occurs in the Givetian–Frasnian of Russia, Kazakhstan and Armenia (Dubatolova and Yeltyschewa 1961; Dubatolova 1971; Yeltyschewa and Stukalina 1977), and Givetian of France (Le Menn 1985).

***Laudonomphalus humilicarinatus* (Yeltyschewa in Dubatolova and Yeltyschewa, 1961)** (Fig. 3I).—The species is known from the uppermost Emsian–Early Frasnian of the Holy Cross Mountains, the Givetian of Silesia-Cracow region and the Early Frasnian of the Sudetes (see Głuchowski 1993). Moreover, the species is widely distributed in the Early–Middle Devonian of Russia and Middle Devonian of Armenia (Dubatolova and Yeltyschewa 1961; Dubatolova 1971; Yeltyschewa and Stukalina 1977).

Family Kstutocrinidae Schevtschenko, 1966

***Kstutocrinus* sp.** (Fig. 3J).—The columnals are minute, high and barrel-like with smooth latus. The articular facet is flat with medium to rather large, pentagonal lumen. The crenularium is very narrow composed of thick culmina. The columnals are similar to those of *Kstutocrinus depressus* Le Menn, 1985 described from Emsian Beg an Arreun Formation of the Armorican Massif, France (Le Menn 1985), but differ in having flat areola and relatively larger lumen.

Family Schyschcatocrinidae Dubatolova, 1971

***Schyschcatocrinus multiformis* Głuchowski, 1993** (Fig. 3K).—The species was reported from numerous Givetian–Frasnian localities in the Holy Cross Mountains (see Głuchowski 1993).

P. ZPAL O. 57/16, sample Id-W-31, carapace in right lateral (P_1) and ventral (P_2) views. **R**. *Bairdia* sp. A, ZPAL O.57/17, sample Id-W-31, carapace in right lateral view. **S**. *Bairdia* sp. B, ZPAL O.57/18, sample Id-W-17, carapace in right lateral view. **T**. *Bairdia* (*Rectobairdia*) *paffrathensis* Kummerow, 1953, ZPAL O.57/19, sample Id-W-39, carapace in right lateral view. **U**. *Bairdia* sp. C, ZPAL O.57/20, sample Id-W-9, carapace in right lateral view. **V**. *Acratia tichonovitchi* Egorov, 1953, ZPAL O. 57/21, sample Id-W-31, carapace in right lateral view. **W**. *Orthocypris* sp., ZPAL O.57/22, sample Id-W-9, carapace in right lateral view. **X**. *Schneideria groosae* Becker, 1971, ZPAL O.57/23, sample Id-W-9, carapace of juvenile specimen in left lateral view. **Y**. *Scrobicula* sp. aff. *S. capsa* Becker, 1971, ZPAL O.57/24, sample Id-W-25, right valve in lateral view. Scale bars 200 μm.

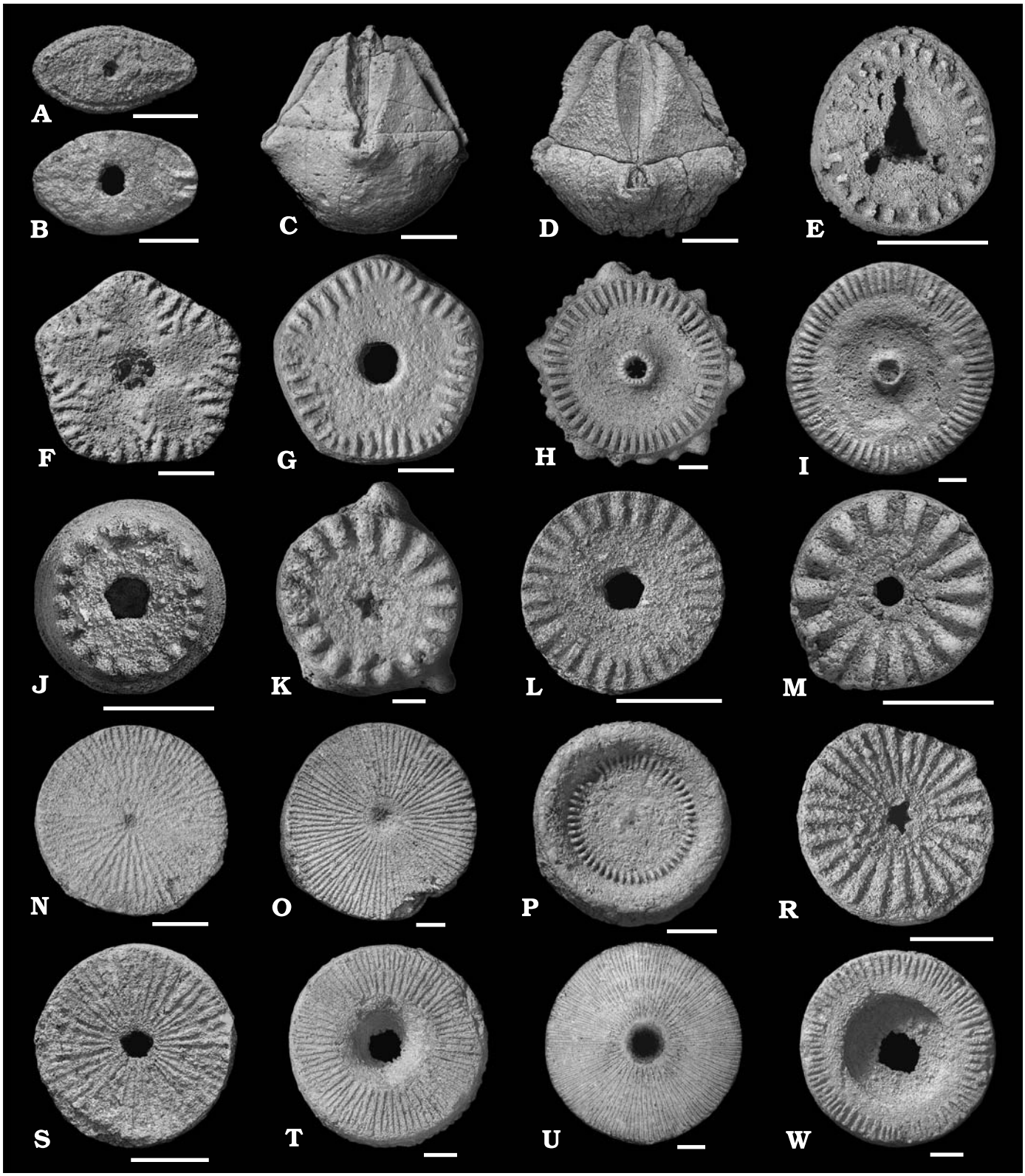

Fig. 3. Early–Middle Frasnian crinoids from the Wietrznia Ie section, Holy Cross Mountains. **A**, **B**. *Platycrinites* sp. **A**. GIUS-4-404/2, sample Ie-66, articular facet with very weakly developed fulcrum. **B**. GIUS-4-404/3, sample Ie-66, articular facet with marginal culmina. **C**, **D**. *Haplocrinites* sp. **C**. GIUS-4-404/5, sample Ie-48, theca from A-ray side. **D**. GIUS-4-404/6, sample Ie-48, theca from E-ray side. **E**. *Cupressocrinites* sp., GIUS-4-404/8, sample Ie-19. **F**. *Floricrinus* sp., GIUS-4-404/6, sample Ie-66. **G**. *Anthinocrinus wenjukowi* Yeltyschewa in Yeltyschewa and Stukalina, 1977, GIUS-4-404/15, sample Ie-34. **H**. *Marettocrinus kartzevae* (Yeltyschewa and Dubatolova in Dubatolova and Yeltyschewa, 1961), GIUS-4-404/10, sample Ie-19. **I**. *Laudonomphalus humilicarinatus* (Yeltyschewa in Dubatolova and Yeltyschewa, 1961), GIUS-4-404/7, sample Ie-19. **J**. *Kstutocrinus* sp., GIUS-4-404//13, sample Ie-66. **K**. *Schyschcatocrinus multiformis* Głuchowski, 1993, GIUS-4-404/16, sample Ie-19. **L**. *Schyschcatocrinus delicatus* Głuchowski, 1993, GIUS-4-404/14, →

***Schyschcatocrinus delicatus* Głuchowski, 1993** (Fig. 3L).—The species is known from the Givetian–Famennian of the Holy Cross Mountains and the Givetian and Frasnian of the Silesia-Cracow region (see Głuchowski 1993, 2002).

Family Stenocrinidae Dubatolova, 1971

***Stenocrinus raricostatus* Głuchowski, 1993** (Fig. 3M).—The species was reported from numerous Givetian–Frasnian localities in the Holy Cross Mountains, the Givetian of the Silesia-Cracow region and the Early Frasnian of the Sudetes (see Głuchowski 1993).

***Calleocrinus kielcensis* Głuchowski, 1993** (Fig. 3N, O).—The species is known from numerous Frasnian-Famennian localities in the Holy Cross Mountains and probably occurs also in the Frasnian of the Dinant Basin, Belgium (see Głuchowski 1993, 2002).

***Glyphidocrinus infimus* (Dubatolova, 1964)** (Fig. 3P).—The species was reported from other Frasnian localities in the Holy Cross Mountains and Silesia-Cracow region (see Głuchowski 1993). The species was initially described from Frasnian Kurlyak Horizon of the Kuznieck Basin, Russia (Dubatolova 1964).

Family Salairocrinidae Dubatolova, 1971

***Tjeecrinus simplex* (Yeltyschewa, 1955)** (Fig. 3R).—The species is also known from other Givetian–Frasnian localities in the Holy Cross Mountains, the Late Givetian of the Silesia-Cracow region and the Early Frasnian of the Sudetes (see Głuchowski 1993). The species was initially described from Givetian Beisk Horizon of the Minusinsk Basin, Russia (Yeltyschewa 1955; Dubatolova 1975).

***Salairocrinus* sp.** (Fig. 3S).—The columnals have smooth, straight or slightly convex latus. The articular facet is flat and completely covered with moderately thick, straight culmina. The lumen is medium-sized, pentagonal. Generally, the articulum resembles that of *Salairocrinus kerevenensis* Le Menn, 1985 described from Givetian Lanvoy and Kerbélec Formations of the Armorican Massif, France (Le Menn 1985), but differs in having finer crenulation and relatively smaller lumen.

Family Peribolocrinidae Dubatolova, 1971

***Peribolocrinus* sp.** (Fig. 3T).—The columnals have smooth and straight latus. The articular facet is slightly concave in the central part and covered with moderately thin culmina. The lumen is medium-sized, circular. The columnals are similar to those of *Peribolocrinus paludatus* (Dubatolova, 1964) described from Lochkovian Krekov Beds of the Kuznetsk Basin, Russia (Dubatolova 1964), but differ in having coarser culmina, relatively smaller lumen and smooth, straight latera.

***Cycloocetocrinus* sp.** (Fig. 3U).—The columnals have straight and smooth latus. The articular facet is flat and covered completely with numerous, dichotomous and thin culmina. The lumen is small to medium-sized, circular. The columnals resemble those of *Cycloocetocrinus scabiosus* Dubatolova, 1980 described from Eifelian Sokol Beds of the Altai, Russia (Dubatolova 1980), but differ in having smooth latus, without ornamentation. Family Tantalocrinidae Le Menn, 1985.

***Tantalocrinus* sp.** (Fig. 3W).—The columnals have straight and smooth latus. The articular facet is flat and bordered by narrow crenularium composed of straight or dichotomous, moderately thin culmina. The lumen is very wide and circular. Some better preserved specimens display thin claustrum constricting axial canal. The columnals are most similar to those of *Tantalocrinus scutellus* Le Menn, 1985 reported from Givetian Lanvoy and Kerbélec Formations of the Armorican Massif, France (Le Menn 1985), as well as from Givetian Skały Beds (upper part) and Laskowa Góra Beds of the Holy Cross Mountains (Głuchowski 1993), but differ in lacking ornamented latus.

Succession of the ostracod faunas

The whole ostracod fauna has been documented solely in set C (*Palmatolepis transitans* Zone) of the Wietrznia Id-W section and comprises twenty three species. Most of the ostracod species belong to the podocopid superfamilies Bairdiocypridoidea (*Micronewsomites*, *Microcheilinella*, *Bairdiocypris*), Bairdioidea (*Bairdia*, *Acratia*, *Bairdiacypris*, *Orthocypris*), and Healdioidea (Metacopina) with *Healdianella* and *Cytherellina* genera. Only four species belong to previously described taxa: *Bairdia* (*Rectobairdia*) *paffrathensis*, *Schneideria groosae*, *Acratia tichonovitchi*, and *Healdianella* cf. *alba*. Palaeocopid ostracods are represented by rare specimens of *Amphissites* sp. and *Hollinella* sp.

The maximum diversity and abundance of ostracods can be observed in the lower and middle parts of set C (samples Id-W-9, Id-W-17, Id-W-27, and Id-W-31) (Fig. 4). In the lower part of set C ostracods are mainly represented by *Microcheilinella* and *Bairdia* species.

On the contrary, a poorly diversified ostracod fauna oc-

sample Ie-66. **M**. *Stenocrinus raricostatus* Głuchowski, 1993, GIUS-4-404/18, sample Ie-27. **N**, **O**. *Calleocrinus kielcensis* Głuchowski, 1993. **N**. GIUS-4-404/20, sample Ie-66, articular facet completely covered with culmina. **O**. GIUS-4-404/21, sample Ie-66, articular facet with culmina nearly reaching the lumen. **P**. *Glyphidocrinus infimus* (Dubatolova, 1964), GIUS-4-404/19, sample Ie-48. **R**. *Tjeecrinus simplex* (Yeltyschewa, 1955), GIUS-4-404/30, sample Ie-48. **S**. *Salairocrinus* sp., GIUS-4-404/33, sample Ie-66. **T**. *Peribolocrinus* sp., GIUS-4-404/9, sample Ie-19. **U**. *Cycloocetocrinus* sp., GIUS-4-404/8, sample Ie-66. **W**. *Tantalocrinus* sp., GIUS-4-404/35, sample Ie-48. Scale bars 1 mm.

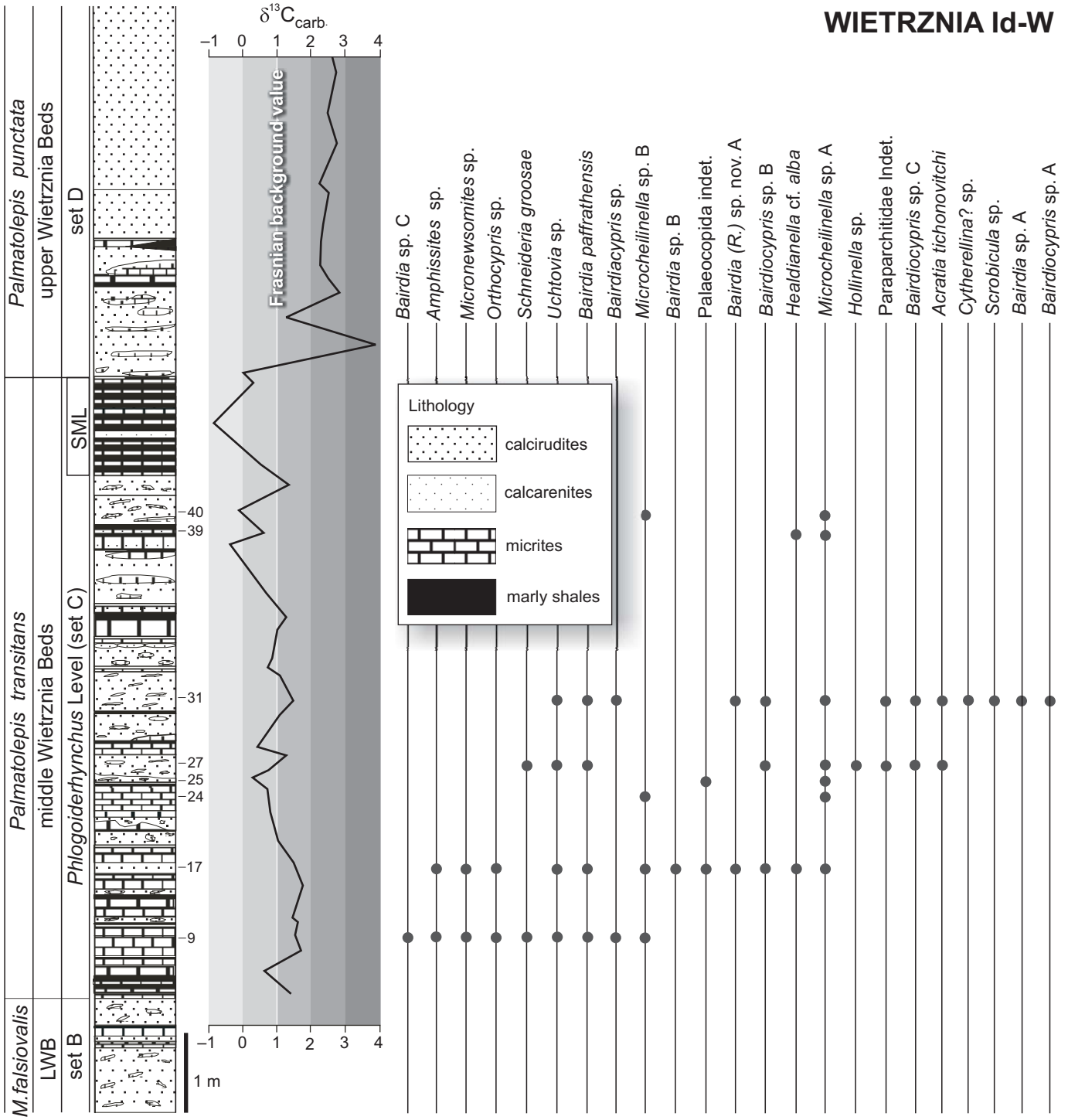

Fig. 4. Stratigraphic distribution of the Early Frasnian ostracod species in the Wietrznia Id-W section, Holy Cross Mountains. Lithology, stratigraphy and stable carbon isotope geochemistry modified from Pisarzowska et al. (2006). Abbreviations: LWB, lower Wietrznia Beds; SML, Śluchowice Marly Level.

curs in succeeding levels, correlated with the upper part of set C (samples Id-W-39 and Id-W-40). Five ostracod species [*Bairdia* (*Rectobairdia*) *paffrathensis*, *Microcheilinella* sp. A, *Microcheilinella* sp. B, *Healdianella* cf. *alba*, and *Bairdia* (*Rectobairdia*) sp. nov. A] have been identified in this part of the section. In general, ostracod faunas from the Wietrznia Id-W section are poorly diversified.

Succession of the crinoid faunas

The Early–Middle Frasnian crinoids from Wietrznia represent the declined stage of the Late Givetian–Middle Frasnian *Schyschcatocrinus* (Smd) assemblage development in the Holy Cross Mountains (Głuchowski 1993). The distribution

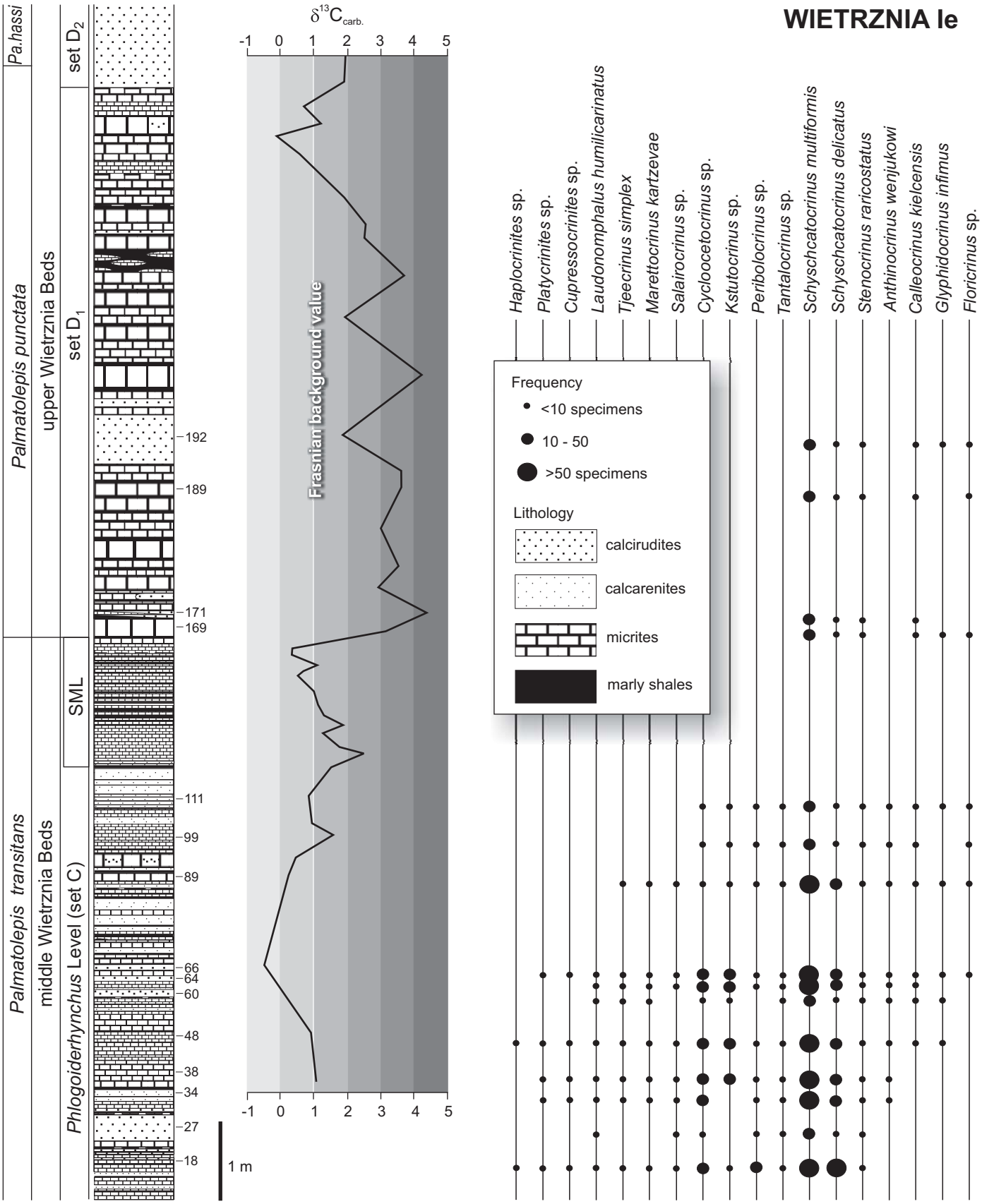

Fig. 5. Stratigraphic distribution of the Lower–Middle Frasnian crinoid species in the Wietrznia Ie section, Holy Cross Mountains. Lithology, stratigraphy and stable carbon isotope geochemistry modified from Pisarzowska et al. (2006). Abbreviation: SML, Śluchowice Marly Level.

pattern of this crinoid assemblage is controlled by eustatic sea-level changes and corresponds to the transgressive-regressive cycles (T-R) of Johnson et al. 1985 (see also Racki 1993, 1997). The Smd crinoid assemblage development was already initiated by the deepening event of the T-R cycle IIb during the *Klapperina disparilis* Chrone in the Kostomłoty area. Subsequently, the crinoid faunas dominated by *Schyschcatocrinus multiformis* and *Schyschcatocrinus delicatus* occupied gradually drowning south-lying shelf areas, they displayed, however, reduced taxonomic diversity resulting from more restricted marine environments (Głuchowski 1993: fig. 19B). They appeared in the Late *Mesotaxis falsiovalis* Chrone in the Northern Kielce subregion. The final colonization of the Central and Southern Kielce subregions in the Early–Middle Frasnian was associated with eustatic sea level rises of the T-R subcycle IIb/c and T-R cycle IIc (Johnson et al. 1985; Racki 1993). The Smd crinoid assemblage during *Palmatolepis transitans–Palmatolepis punctata* chrones was widely distributed in the Holy Cross Mountains, but displayed the lowest taxonomic diversity (Głuchowski 1993: fig. 19A).

The whole crinoid fauna from the Wietrznia Ie section comprises eighteen species including the representatives of *Haplocrinites*, *Platycrinites*, and *Cupressocrinites*, as well as fifteen stem-based taxa distributed in both Early Frasnian (*Pa. transitans* Zone) set C and Middle Frasnian (*Pa. punctata* Zone) set D_1 (Fig. 5). The crinoid ossicles are particularly frequent within the set C (samples Ie-18 to Ie-111), except its ca. 1.5 m topmost part (= Śluchowice Marly Level), lacking of crinoids. The crinoids appeared once again in this section at the base of the set D_1. Still, they were documented in the lower part of the *Pa. punctata* Zone (samples Ie-169 to Ie-192), but in small abundance. All distinguished crinoid taxa occur within the brachiopod-rich set C, whereas only six of them are reported from the set D_1. The rich Early Frasnian crinoid fauna is dominated by *Schyschcatocrinus multiformis* and *Schyschcatocrinus delicatus*. In the whole interval twelve crinoid taxa disappeared, but just as many were newly introduced, and among them the index species *Calleocrinus kielcensis*. The surviving Middle Frasnian crinoid fauna was impoverished, but still remained enriched in schyschcatocrinids. Moreover, four of these surviving crinoid species entered *Calleocrinus–Schyschcatocrinus* (CkSm) assemblage documented in the Middle Frasnian *Pa. punctata–Pa. hassi* zones of the Northern Kielce and Southern Kielce subregions (see Głuchowski 1993). Generally, the crinoid distribution pattern comprises the interval of maximum abundance and diversity, interrupted in the uppermost *Pa. transitans* Zone and the interval of temporary recovery in the lower *Pa. punctata* Zone (Fig. 5). On the other hand, the Early–Middle Frasnian crinoid distribution pattern in the Wietrznia I quarry differs from that observed in the Northern France. The *Pa. transitans–Pa. punctata* boundary in the Boulonnais area runs within the Noces Member, Beaulieu Formation (Morzadec et al. 2000), and a significant increase of the taxonomic crinoid diversity is observed just above this boundary (see Le Menn 1988: fig. 1). This crinoid diversity rise was associated strongly with the deepening pulse of the T-R cycle IIc.

Palaeoenvironmental comments

The association of ostracods present in set C of the Wietrznia quarry belongs to the Eifelian Mega-Assemblage and is indicative of a well-oxygenated shallow marine environment. Thuringian-type ostracods which are principally thin-shelled, spinose podocopine species, indicative of low energy, and probably deeper marine environments are absent in the Wietrznia Id-W section. Myodocopid ostracods indicative of strong hypoxic water conditions are also absent.

In the lower part of set C, the Bairdiocyprididae (*Bairdiocypris*) are well represented. These thick shelled taxa have been described from many Middle and Late Devonian shallow water assemblages of high-energy environments. Fossil bairdiids (*Bairdia*, *Acratia*) are indicative of near-shore to bathyal palaeoenvironments, and *Bairdia* is believed to be characteristic of open-marine environments. They are also abundant in the pelagic realm. The quasi absence of Metacopina is also significant because in the open-marine environment they are indicative of deeper and quiet environments. Consequently, the environment in the lower part of set C was certainly very shallow, well oxygenated, in fact close to fair weather wave base. In the upper part of the set C, ostracods are abundant again but they are represented by only five species in sample Id-W-39 and two species in sample Id-W-40. The low diversity and the fact that the two most abundant species belong to the genus *Microcheilinella* indicates an episodic increase of the water energy recorded in reef-breccia deposits (Fig. 4). This is also confirmed by the great number of broken carapaces found in detrital limestone sample Id-W-40 (intraformational conglomerate).

Of the 23 species occurring in the Early Frasnian, none survived the crisis interval (set C/set D boundary) in the investigated section. However, the absence of ostracods in the *Pa. punctata* Zone is not adequate to demonstrate conclusively an extinction during the Early–Middle Frasnian biotic crisis. This absence is certainly in great part related to biostratinomical factors due to the unprofitable changes of the water energy in the sedimentary environment.

The Early Frasnian ostracod assemblage from the Kadzielnia (Kadzielnia Limestone Member; see discussion of dating in Pisarzowska et al. 2006), described by Malec and Racki (1992) is characterized by the domination of palaeocopid species *Fellerites* sp., platycopid *Uchtovia* sp., and podocopid species *Bairdia* sp., *Bairdiocypris* sp., and *Microcheilinella* sp. The remaining 13 palaeocopid, platycopid and podocopid species do not exceed a few percent of samples. Differences in the character of ostracod assemblages between Kadzielnia and Wietrznia sections are mainly expressed by the lower relative frequency of palaeocopid and platycopid species in Wietrznia.

Both crinoid and ostracod distribution patterns point to environmental changes across Early–Middle Frasnian transition

coinciding with a C-isotopic perturbation reported from the Wietrznia sections by Racki et al. (2004) and Pisarzowska et al. (2006). The uppermost *Palmatolepis transitans* Zone interval, deprived of crinoids and ostracods, corresponds to a negative δ^{13} C excursion (= event II of Racki et al. 2004 and Pisarzowska et al. 2006), while temporary recovery of impoverished crinoid faunas coincides with distinctive, long-term positive δ^{13} C excursion in the *Pa. punctata* Zone (= event III of Racki et al. 2004 and Pisarzowska et al. 2006). Such a disturbed crinoid distribution pattern reflects an intermittent, two-step eustatic sea level rise (T-R subcycle IIb/c and T-R cycle IIc) postulated by Racki (1993). On the other hand, these impoverished, surviving crinoid faunas and the absence of ostracods in the *Pa. punctata* Zone are associated with overall unprofitable changes in their habitats during the Middle Frasnian heavy-carbon interval (see summary in Pisarzowska et al. 2006 and Sobstel et al. 2006). This deterioration of life conditions could partly result from synsedimentary tectonic pulses causing block movements and large-scale resedimentation phenomena on the northern slope of the Dyminy Reef during the basal Middle Frasnian sea level rise (see Racki and Narkiewicz 2000). It is obvious that these phenomena associated with occasional increase of the bottom water turbidity were unfavorable for benthic communities. It can be assumed that these environmental changes were also sensible for brachiopods as their last occurrences in this section were registered near *Pa. transitans–Pa. punctata* boundary (see Baliński 2006). However, it appears that these changes were of local importance because a decrease of taxonomic diversity among crinoids from the Southern Kielce subregion (e.g., Kowala railway cut) in the lower part of the *Pa. punctata* Zone (set D) has not been recorded (see Głuchowski 1993).

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