

Middle/Upper Devonian brachiopod shell concentrations from the intra-shelf basinal carbonates of the Holy Cross Mountains (central Poland)

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ABSTRACT:

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A huge isolated accumulation, more than 3 m thick and 10 m wide, of densely packed, uncrushed brachiopods has been found in Józefka Quarry within the Middle/Upper Devonian Szydłówek Beds deposited in a relatively deep environment of an intrashelf basin (Kostomłoty facies zone, western Holy Cross Mountains, Poland). The low-diversity assemblage is strongly dominated by the atrypide *Desquamatia globosa jozefkae* Baliński subsp. nov. and, to a lesser degree, by the rhynchonellide *Coeloterorhynchus dillanus* (Schmidt, 1941), which constitute 72.8% and 22.1% of the fauna, respectively. Less frequent are specimens representing the genera *Hypothyridina*, *Schizophoria* and *Phlogoiderynchus*. According to the conodont fauna found within the coquina bed, the stratigraphic position of the shell accumulation is close to the Givetian/Frasnian boundary. The brachiopods are associated with numerous crinoids and less frequent bryozoans, receptaculitids (Palaeozoic problematica), sponges and solitary corals. Although it is difficult to entirely exclude the autochthonous nature of the brachiopod coquina member, its allochthonous origin and redeposition of the brachiopod shells to the deep basin by gravity flows is much more probable. Such conclusion is supported by the following facts: (1) the position of the complex in a succession of deep-marine basinal facies impoverished in oxygen; (2) its lateral thinning-out and composite internal stratification; (3) the lens-shaped geometry of the coquina bed in the section perpendicular to the bedding dip; (4) high variability of the sediments preserved within the shells; and (5) the preferred orientation of the shells. The brachiopods mixed with crinoidal debris were probably transported by low-velocity, high-density, gravity-induced debris flows. Lack of fossils typical of the Middle Devonian shallows, such as massive stromatoporoids, amphiporoids and tabulates, indicates that the source area of the bioclastic material was not located in the shallowest part of the shelf, but most probably on a submarine sea-mount to the north of present-day Józefka, as suggested by earlier investigators. The triggering mechanism of the allochthonous deposition was an earthquake rather than storm activity. The enormous thickness of the brachiopod complex is probably caused by the sinking of bioclastic material, transported in succeeding depositional multi-events, in a soft, muddy bottom, typical of the Szydłówek Beds deposition.

Key words: Devonian; brachiopods; Holy Cross Mountains; allochthonous origin of coquina.

INTRODUCTION

The incentive to the investigations reported in this paper was the finding of a huge lens of brachiopod coquina within the Middle/Upper Devonian intra-shelf basinal limestone-marl succession in the Holy Cross Mountains (central Poland). The brachiopod shell accumulation was discovered during a field reconnaissance in the MSc thesis area of Inga Zawadzka, supervised by the first author. The extent of the lens exceeded 10 m, whereas its maximal thickness was about 3 m. The huge size of the densely packed brachiopod coquina, rarely found in Phanerozoic successions (except of the upper Silurian to Upper Devonian successions of the Moroccan Meseta), triggered numerous questions on the sedimentological and taphonomic nature of such brachiopod occurrence.

The appearance of brachiopod beds in the Devonian bituminous limestones/marls of Józefka Hill near Górnó village in the Holy Cross Mountains, Poland (Text-fig. 1A, C) has been known for a long time, and expansion of the quarry located on the top of the hill during the last 30 years has disclosed a large number of thin brachiopod beds. In spite of their attractiveness for collectors, they have remained palaeontologically undescribed, with only short remarks being published by Szulczewski (1971), Małkowski (1981), Racki (1993a, b) and Vierek (2008, 2014). The first *stricto* palaeontological monograph dedicated to brachiopods from some parts of the Józefka succession appeared just 2 years ago (Baliński *et al.* 2016).

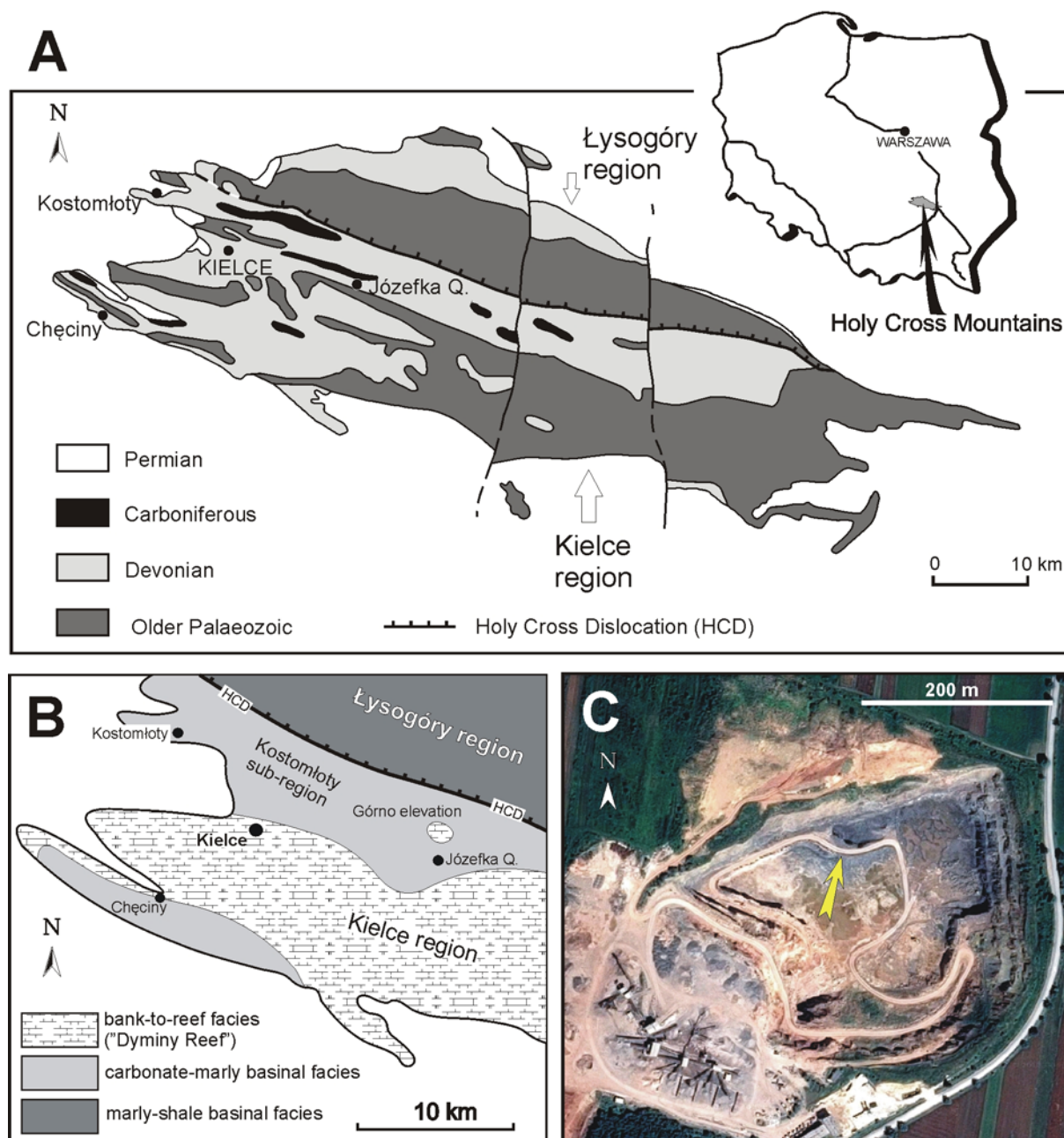
More than 20 years ago the first author had the pleasure to collect the perfectly preserved and locally abundant brachiopods in the small Józefka Quarry together with the late Professor Andrzej Radwański. The specific feature of these brachiopods was the frequent infilling of their shells with black, dense hydrocarbon fluids. Professor Radwański's passion for collecting beautiful fossils was commonly known, and it was a recurrent view when he patiently dusted his collection of Devonian trilobites, Miocene shark teeth or Jurassic echinoids. Parts of this collection have been already described (see publication list in Walaszczyk, this volume), whereas other were enriched year by year, waiting for public presentation. The brachiopods from Józefka Quarry belong to this last group.

REGIONAL AND STRATIGRAPHIC SETTING

Józefka Hill is situated in the western part of the Holy Cross Mountains (Text-fig. 1A, C), not far from Górnó village, in the southern limb of the Radlin

Syncline, one of the main tectonic units in the Holy Cross Mountains Fold Belt (e.g., Czarnocki 1938; Konon 2007). The hill is composed of Devonian carbonate rocks developed in facies characteristic of the Kostomłoty sub-region, a transitional zone between the shallow-water carbonate platform (Kielce Region) and the deep-water intra-shelf basin dominated by marly and shaly sediments (Łysogóry Region) (Czarnocki 1957; Szulczewski 1971, 1995; Racki 1993b; Text-fig. 1B). Most probably, a submarine elevation was located in the vicinity of Górnó village, within the basin; it played an important role in the explanation of the brachiopod bed investigated herein (Text-fig. 1B). Józefka Quarry is only one of the several quarries in the area of the Holy Cross Mountains where it is possible to investigate the thick Devonian succession typical of the southern, tropical shelf of Laurussia (Scotese and McKerrow 1990; Narkiewicz 2007; Belka and Narkiewicz 2008; Golonka and Gawęda 2012). In the quarry studied, a stratigraphic sequence from the Givetian to the Famennian has been exposed for some decades, but the possibility to perform research is limited here by the quarry activities, intense faulting and numerous overthrusts, which strongly perturb the stratigraphic order. Hence, the recognition of the Devonian succession was hitherto mostly based on observations performed in the close proximity of the quarry, along a road escarpment situated to the east of it (Małkowski 1981; Racki *et al.* 1985; Racki and Bultynck 1993; Baliński *et al.* 2016).

According to Baliński *et al.* (2016), the lower part of the exposed Devonian succession is composed of the following informal stratigraphic units (in ascending order): (1) dolomites, (2) Laskowa Góra Beds, and (3) Szydłówek Beds with their uppermost time-equivalent Wietrznia Beds (Text-fig. 2). This succession is covered by deposits of the Kostomłoty Beds, composed of nodular limestones intercalated with litho- and bioclastic limestones, intraformational breccias and conglomerates, interpreted as gravity flow deposits, transported from the southern carbonate platform or its slope to the northwardly located basin (Szulczewski 1971, 1995). The sequence records the early stages of drowning of the carbonate platform margin. The bulk of the dolomites represents its dolomitised part, originally composed mainly of stromatoporoid-coral limestones, and the Laskowa Góra Beds correspond to its marginal, retreating wedge. The Szydłówek Beds are initial intra-shelf slope-to-basin deposits, which encroached upon the carbonate platform after its tectonic disintegration and drowning of its northern external parts (Szulczewski *et al.* 1996). The brachiopod shell accumulation, which is the main focus of

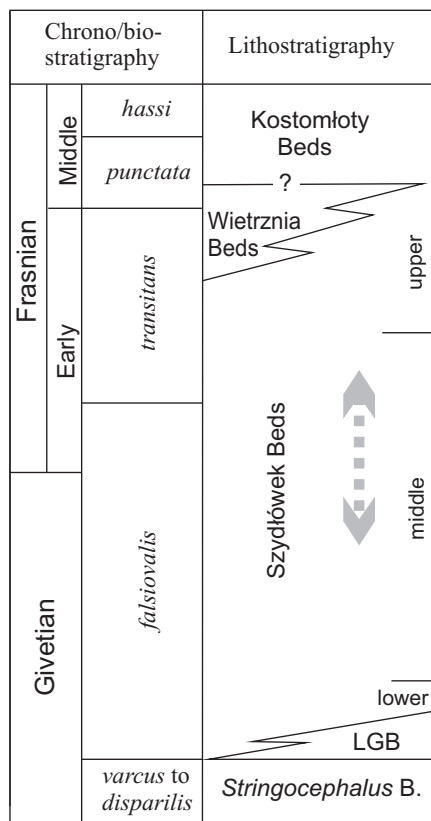


Text-fig. 1. Location of the investigated section. A – Geological map of the Palaeozoic inlier of the Holy Cross Mountains with location of Józefka Quarry (simplified after Geological Map of Poland without Quaternary formations, 1977, 1:500 000, edited by the Polish Geological Institute); B – Palaeofacies map of the Middle Devonian in the Holy Cross Mountains (after Racki 1993b); C – Location of the investigated section on the satellite photo of Józefka Quarry (modified from Google Maps: <http://maps.google.com>)

this paper, occurred within the Szydłówek Beds in the north-western wall of the quarry, but at present it is completely removed by quarry activities.

Even at a short distance from the road leading to the western part of the quarry the stratigraphic succession differs substantially from the basic scheme

presented above. The Laskowa Góra Beds are not present in this part of the section and the Szydłówek Beds contact directly with the dolomites. However, the uppermost part of the dolomites is partly black here and the only recognisable fossils they contain are abundant remains of crinoids and brachiopods,



Text-fig. 2. Approximate stratigraphic position of the investigated shell bed. Regional stratigraphic scheme after Baliński *et al.* (2016, text-fig. 3); LGB refers to Laskowa Góra Beds

locally even atrypid coquinas. These primary features indicate that the original, later dolomitised deposits, had much in common with the directly overlying Szydlówek Beds. The main primary difference between the two units is that the dolomites are thick-bedded here, whereas the Szydlówek Beds are generally comprehended as thin-bedded, marly-shale rhythmic deposits (Biernat and Szulczewski 1975; Racki 1993b).

These relationships show that the front of mesogenic dolomitisation considerably changed its stratigraphic position even at such short distance from the Józefka Hill area, similarly as it was shown by M. Narkiewicz (1990) in other parts of the Holy Cross Mountains. It also proves that the two-step drowning of the carbonate platform is recorded in this succession, first within the dolomites of the western section, and secondly at the base of the Szydlówek Beds (compare record of eustatic events in the Devonian of the Holy Cross Mountains illustrated by Baliński *et al.* 2016, text-fig. 3)

Conodonts are the only available biostratigraphic tools in the Szydlówek Beds facies. Although their frequency is very low, they prove that the Szydlówek Beds straddle the Middle/Upper Devonian boundary and their base is diachronous (Racki 1985). According to Racki and Bultynck (1993, p. 21), the position of this boundary changes along the regional occurrence of the Szydlówek Beds from the *Klapperina disparilis* Zone in the west to the lowermost *Mesotaxis falsovalis* Zone in the east (Górno). They also suggested that the boundary between the Laskowa Góra Beds and the Szydlówek Beds is placed on Józefka Hill near the *disparilis-falsovalis* zonal boundary (Racki and Bultynck 1993, p. 13).

Recent investigations have changed this opinion, since according to Baliński *et al.* (2016, p. 113, text-fig. 4) the conodonts found in Józefka in the lowermost part of the Szydlówek Beds “suggest strongly the assignment of the Józefka succession to the Lower Frasnian [Palmatolepis] transitans Zone”. Our investigations on the conodont fauna were limited only to the studied shell bed, but their results contradict the latter opinion. Among several samples taken from the brachiopod coquina only one proved stratigraphically useful. It contains the following conodont species: *Icriodus excavatus* Weddige, 1984; *Mehlnia gradata* Youngquist, 1945; *Polygnathus alatus* Huddle, 1934; *Polygnathus dubius* Hinde, 1879; *Polygnathus pollocki* Druce, 1976 and *Polygnathus webbi* Stauffer, 1938. All these species display long ranges and zonal index forms are missing in the sample. Nevertheless, its age can be determined according to their overlapping ranges, which were compiled by K. Narkiewicz and Bultynck (2007, fig. 3; 2010, fig. 9; 2011, fig. 3) and K. Narkiewicz (2011, fig. 3). The concurrent occurrence of *I. excavatus* and *P. webbi* indicates that the sample comes from an interval between the upper part of the lower *falsovalis* Zone to the upper *falsovalis* Zone, and possibly also part of the *transitans* Zone. This interval falls within wider ranges of the remaining species. It is possible that the upper range of *P. dubius* excludes the *transitans* Zone (K. Narkiewicz and Bultynck 2010, fig. 9), but K. Narkiewicz (2011, fig. 3) has shown that it extends many zones above.

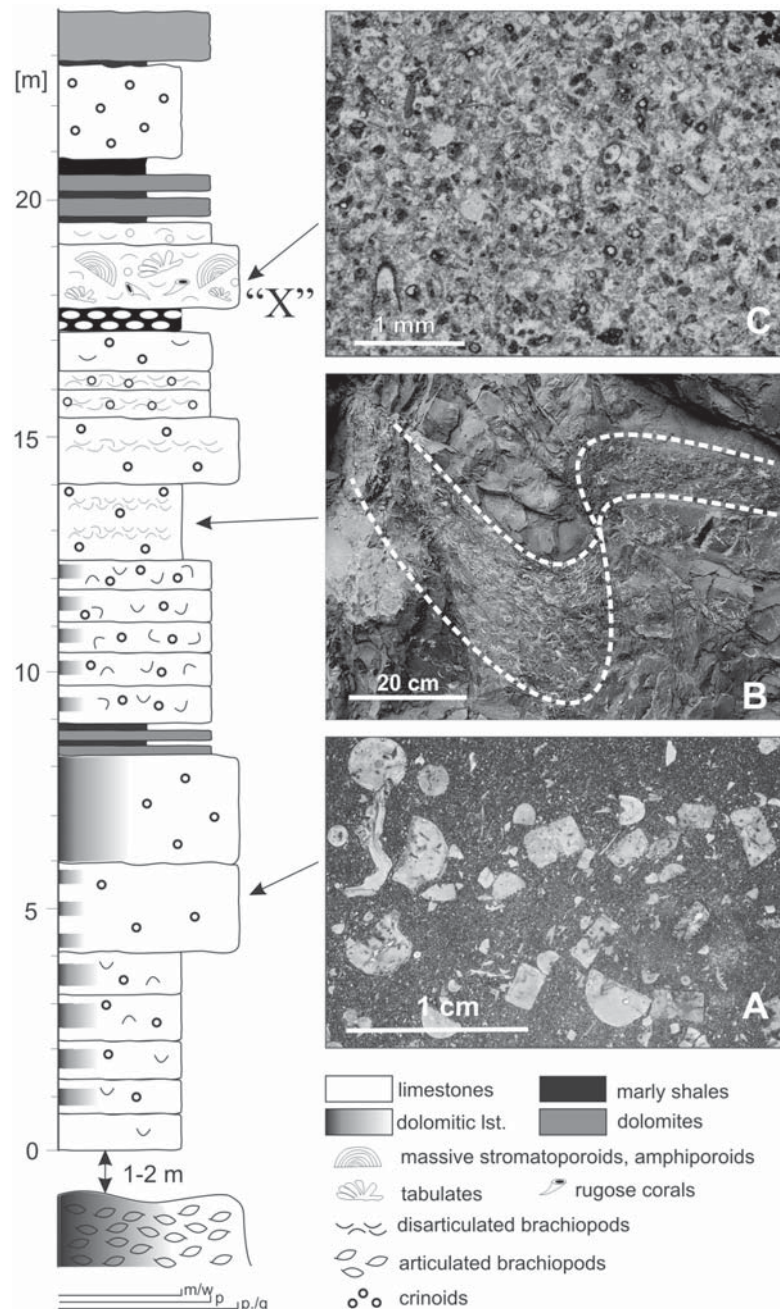
The stratigraphic position of the shell accumulation studied (Text-fig. 2) is close to the Givetian/Frasnian boundary, i.e., the Middle/Upper Devonian boundary. However, its more precise relation to this boundary may not be determined, since, according to Sandberg *et al.* (1989), the position of the discussed boundary falls in an undetermined position within the *falsovalis* Zone.

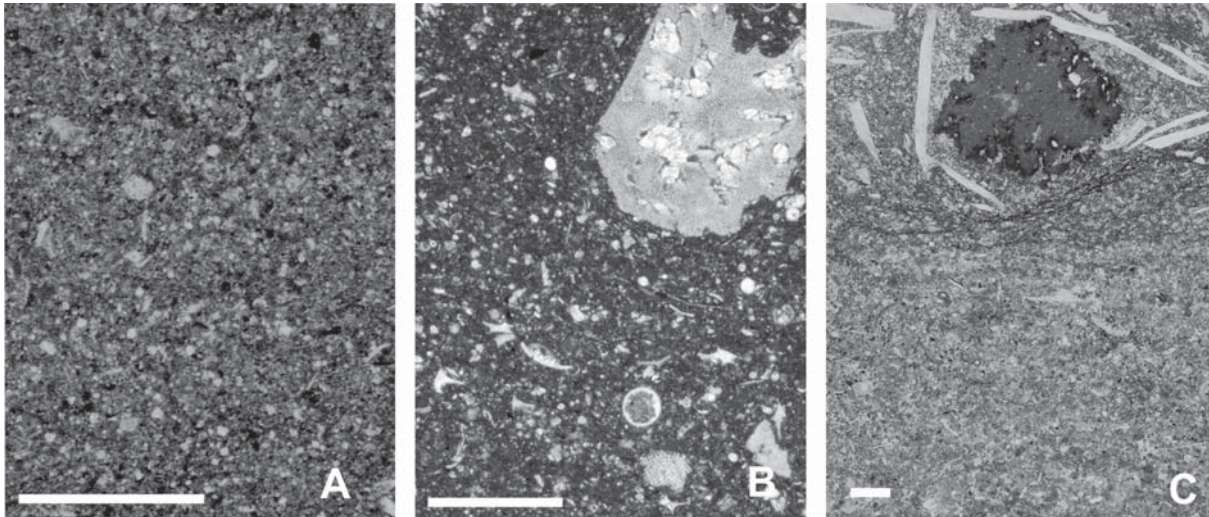
LITHOLOGY OF THE ROCKS SURROUNDING THE COQUINA BED

The coquina bed is located within deposits that in terms of microfacies correspond to the Szydłówek Beds, although macroscopically they are evidently different from the typical examples of this unit, composed of black shales intercalated with limestones (compare Szulczewski 1995; Racki *et al.* 2004; Vierek 2008, 2014). Shale intercalations are less numerous here than in the typical Szydłówek Beds. On

the other hand the limestone layers are more bioclastic, sometimes even coarse-grained. Generally they are developed as bituminous, dark grey and fine-grained limestones/marls, with a generally low number of macrofossils, except of a few layers.

The unit directly underlying the coquina bed is composed of thin-bedded, strongly bituminous, fine-grained bioclastic wackestones, with peloids, sometimes aggregated into grapestones, fine-grained micritic intraclasts and single styliolinids (Text-figs 3, 4A). As an exception appear two layers, several centi-





Text-fig. 4. Examples of microfacies (scale bar = 1 mm): A – fine-grained peloidal packstone, with micritic lithoclasts and styliolinids (unit underlying coquina bed); B – fine-grained packstone with large crinoidal, slightly dolomitised bioclasts (unit underlying coquina bed); C – bioeroded clast in peloidal-calcisphaerid packstone (matrix of the stromatoporoid-tabulate bed X)

metres thick, which represent grainstones/packstones with intraclasts, and crinoid and brachiopod bioclasts (Text-fig. 4B). The matrix of the brachiopod coquina lying above is identical with the dominating wackestone lithology.

The rocks above the interval with the brachiopod coquina are more diversified. They are dominated by medium-bedded wackestones and mudstones. Fossils are represented by fragments of brachiopods, crinoids, rare styliolinids and single ostracodes. Relatively numerous are coarse-grained packstones, composed of peloids, crinoids, bryozoans and brachiopods. Sporadically occur bioeroded intraclasts (Text-figs 3A, 4C). The densely packed and disarticulated brachiopods occur in several beds, forming few-centimetres-thick coquina beds (e.g., Text-fig. 3B). The only exception in this lithological spectrum is a thick bed composed of broken massive stromatoporoids, amphiporoids, alveolitic tabulates, rugose corals and lithoclasts (bed X in Text-fig. 3). The matrix of this layer is completely different from the other beds, being composed of peloids and calcisphaerids (Text-fig. 3C).

A specific feature of the entire complex is its partial dolomitisation, especially in the layers terminating the investigated part of the Józefka section (Text-fig. 3). This part is represented by coarse-grained crystalline dolomites, similar to the dolomites from the lowermost lithostratigraphic complex exposed in the quarry.

According to numerous descriptions of the Szydłówek Beds (i.e., Szulczewski 1971, 1995; Małkowski 1981; Racki *et al.* 1985; Racki and Bultynck 1993; Vierek 2008, 2010, 2014; Baliński *et al.* 2016), this unit is interpreted as deposits of an intra-shelf, stagnant basin. These beds represent an environment deeper than the shallow-water carbonate platform with stromatoporoid-coral carbonates developed in the central part of the Kielce Region. A rapid deepening of sedimentation is interpreted (Racki 1993a; Racki and M. Narkiewicz 2000; Pisarzowska *et al.* 2006) as an effect of eustatic rise (IIb event *sensu* Johnson *et al.* 1985). The Szydłówek Beds were deposited in a hemipelagic environment, with the bottom waters impoverished in oxygen. The sediments are generally poor in fossils (even conodonts), but locally they are intercalated with bioclastic deposits transported from the neighbouring platform. Storms, tsunamis or tectonic movements (earthquakes) are mentioned (Szulczewski 1971, 1995; Vierek 2008, 2014) as mechanisms triggering the gravity flows of bioclastic material transported from the platform. The unit is usually sub-divided into 3 parts (A–C according to Racki and Bultynck 1993), of which the lower one is transitional between shallow and deeper deposits, whereas the upper one is most typical of the unit, with numerous intercalations of bituminous shales. Racki *et al.* (2004) and Vierek (2008) suggested dysoxic conditions in bottom waters during this stage of deposition. In this context the beds in-

vestigated here fully represent the lower unit of the Szydłówek Beds, with only impoverishment of the oxygen content, large enough to a nearly complete absence of benthic fauna. Surprisingly different in respect to the greater size of the bioclasts and their specific spectrum is bed X (Text-fig. 3); its environmental significance is discussed in detail below.

THE BRACHIOPOD COQUINA BED

The investigated brachiopod coquina forms a massive body, with its marginal parts cut by two faults (Text-fig. 5B). It is lens-shaped in a cross-section that is most probably perpendicular to the body elongation. The base of the lens is convex down; the boundaries of this form are conspicuous but not erosional (Text-fig. 5). The coquina bed is densely packed and its fabric seems to be chaotic at first glance (Text-fig. 5C), but detailed observations of a large-scale polished slab reveal a rather regular horizontal orientation of the brachiopod shells and complex internal stratification (Text-fig. 6). The brachiopod assemblage is strongly dominated by the atrypide *Desquamatia globosa jozefkae* Baliński subsp. nov. (Text-figs 7, 8) and, to a lesser degree, by the rhynchonellide *Coeloterorhynchus dillanus* (Schmidt, 1941) (Text-fig. 9A–J, P), which constitute 72.8% and 22.1% of the fauna (N=290 specimens), respectively. These two species contribute to nearly 95% of the assemblage. The remaining three species: *Schizophoria (S.) schnuri prohibita* Halamski, 2012 (Text-fig. 9K, L), *Phlogoiderhynchus polonicus* (Roemer, 1866) (Text-fig. 9O) and *Hypothyridina* sp. (Text-fig. 9M, N) are very rare and less important.

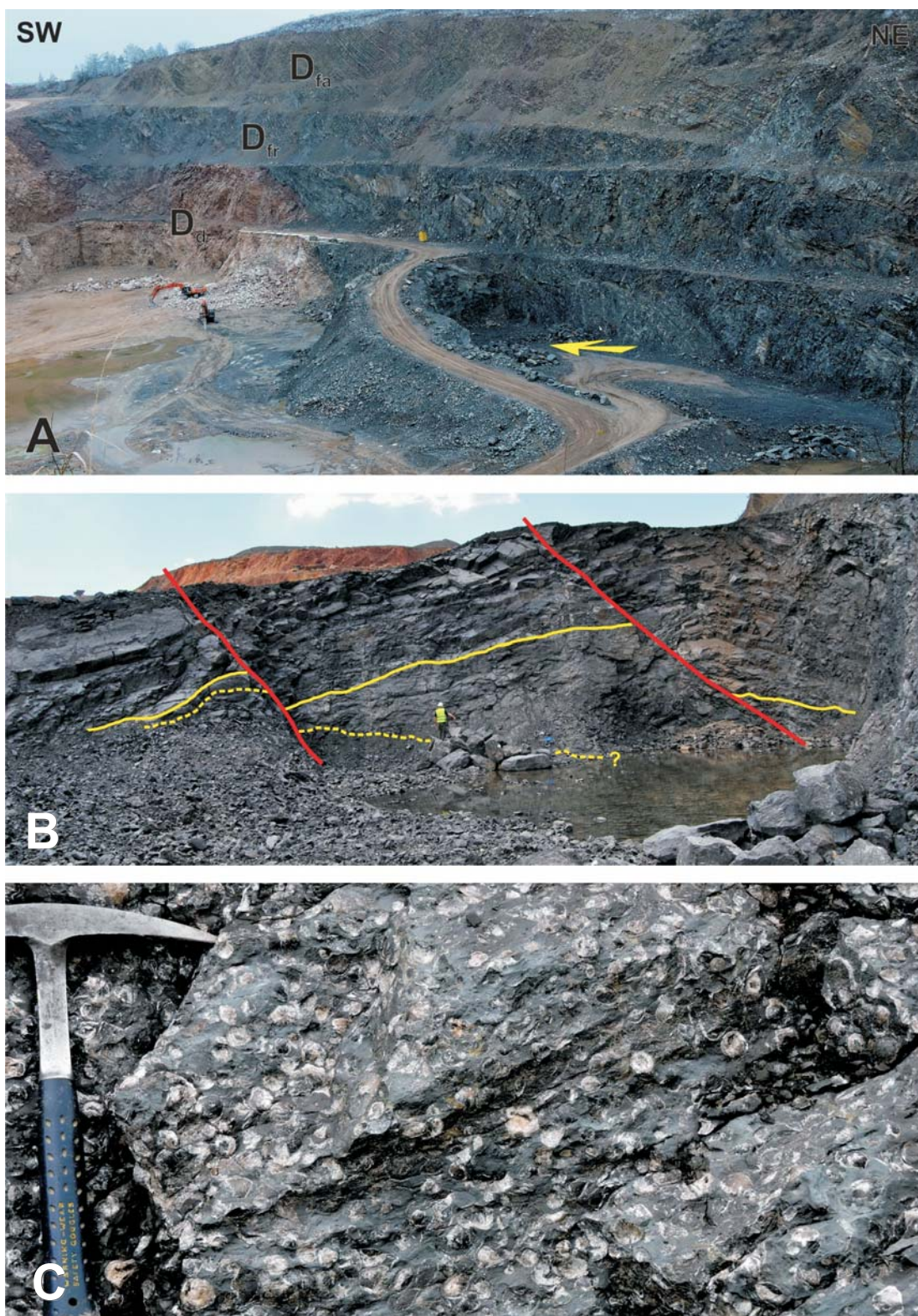
Crinoids are equally numerous as brachiopods in the investigated coquina bed. They are randomly scattered, or occur in the form of more or less regular intercalations or irregular concentrations (Text-fig. 6). Thin crinoidal intercalations within the generally massive body of the coquina bed, as for example the beds presented in Text-fig. 6, are treated here as indicators of the sedimentary surface.

Fistuliporid bryozoans, mostly representing the species *Canutrypa francqana* Bassler, 1952 (Text-fig. 10D) are another, relatively frequent component of the coquina bed. A specific feature of this species is its abundant appearance in the Devonian of the Holy Cross Mountains only in the study area and in some parts of the Chęciny area. According to Morozova *et al.* (2002, p. 308), the section on Józefka Hill near Górnó is “the most productive bryozoan locality in the Kielce Region”. However, this fauna,

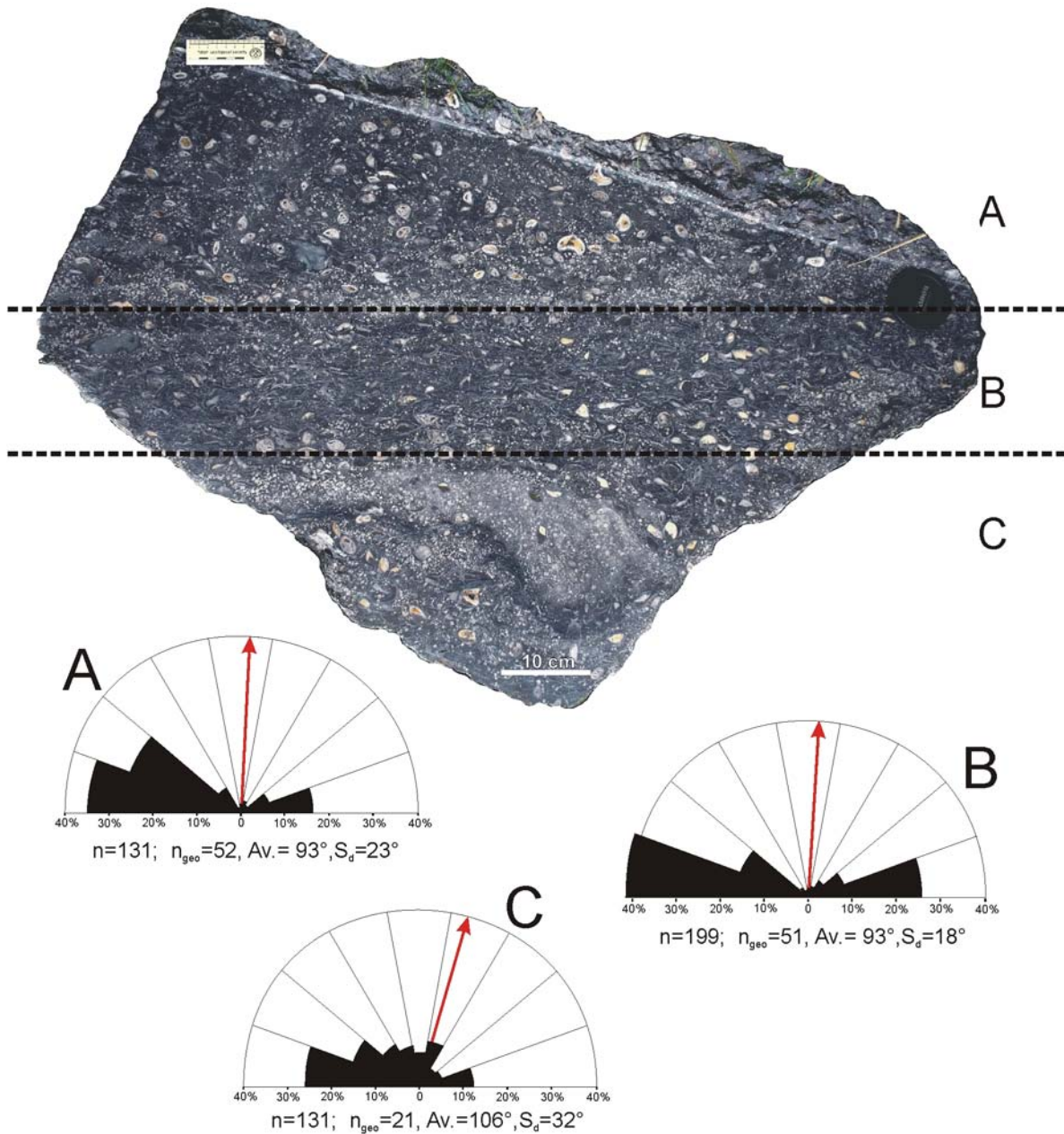
connected with open-shelf, ramp slope or intershoal facies, is of little significance as a facies indicator.

Other components of the assemblage are limited to rare specimens of rugose corals (Text-fig. 10A), receptaculids (Text-fig. 11D) and lithistid demosponges (Text-fig. 10E). Although receptaculids are relatively often mentioned in the descriptions of Devonian fossil assemblages from Poland (Szulczewski 1971; Racki 1993b), these enigmatic fossils have not attained a monographic description yet. Usually they are regarded as components of reefal communities (Szulczewski 1971; Mierzejewska and Mierzejewski 1973; Baliński *et al.* 2016). Different groups of sponges are a more frequent element of the Devonian biotopes in the Holy Cross Mountains (Rigby *et al.* 2001 with complete references), but usually they were described from younger strata (upper Frasnian), limited to the southern part of the region; according to Rigby *et al.* (2001) they have not been reported from the Łysogóry–Kostomłoty regions. In the Kielce Region they were usually associated with the brachiopod-coral-sponge assemblages that inhabited the deep slope of the central carbonate platform in a hemipelagic setting.

Additional, very valued information on the distribution of fossils within the coquina bed is provided by a polished slab (about 1000 cm²) achieved by cutting of a large block of brachiopod limestone (Text-fig. 6). The measurements made on its surface indicate a very regular orientation of the shells. Measurements of the longer axis of brachiopod shell sections were performed in relation to the level of a thin crinoidal intercalation within the coquina, assumedly more or less horizontal during sedimentation. The second reference level was located below, on the boundary between the area of crushed shells and shells that were not deformed during compaction. The crinoidal concentration below this level is irregular and resembles deformational structures caused by a reversed density gradient (compare Dżułyński and Kubicz 1975; Biernat and Szulczewski 1993). As a result, three parts of the slab were distinguished and the presented measurements are related to each part separately (Text-fig. 6). In parts A and C both valves of brachiopod specimens are preserved and all brachiopods are undeformed. In part B both valves are usually also preserved but the specimens are mostly compressed and flattened. However, in many cases both valves of a single specimen were not separated but flattened together. Statistically, in the upper parts (A and B) the longer axes of shells are arranged in a position parallel to the reference level. More than 50% of the measured shells are located in intervals at 0–20° and



Text-fig. 5. Outcrop of the brachiopod coquina bed in Józefka Quarry (state as in 2015). A – General view of the north-western wall of the quarry; direction of wall is more or less parallel to the orientation of the overthrust surfaces; yellow arrow indicates direction of the view presented in B; D_d – dolomite unit, D_{fr} – Frasnian units, D_{fa} – Famennian units; B – General view of the brachiopod coquina lens (yellow boundaries); C – close-up of the investigated brachiopod coquina bed

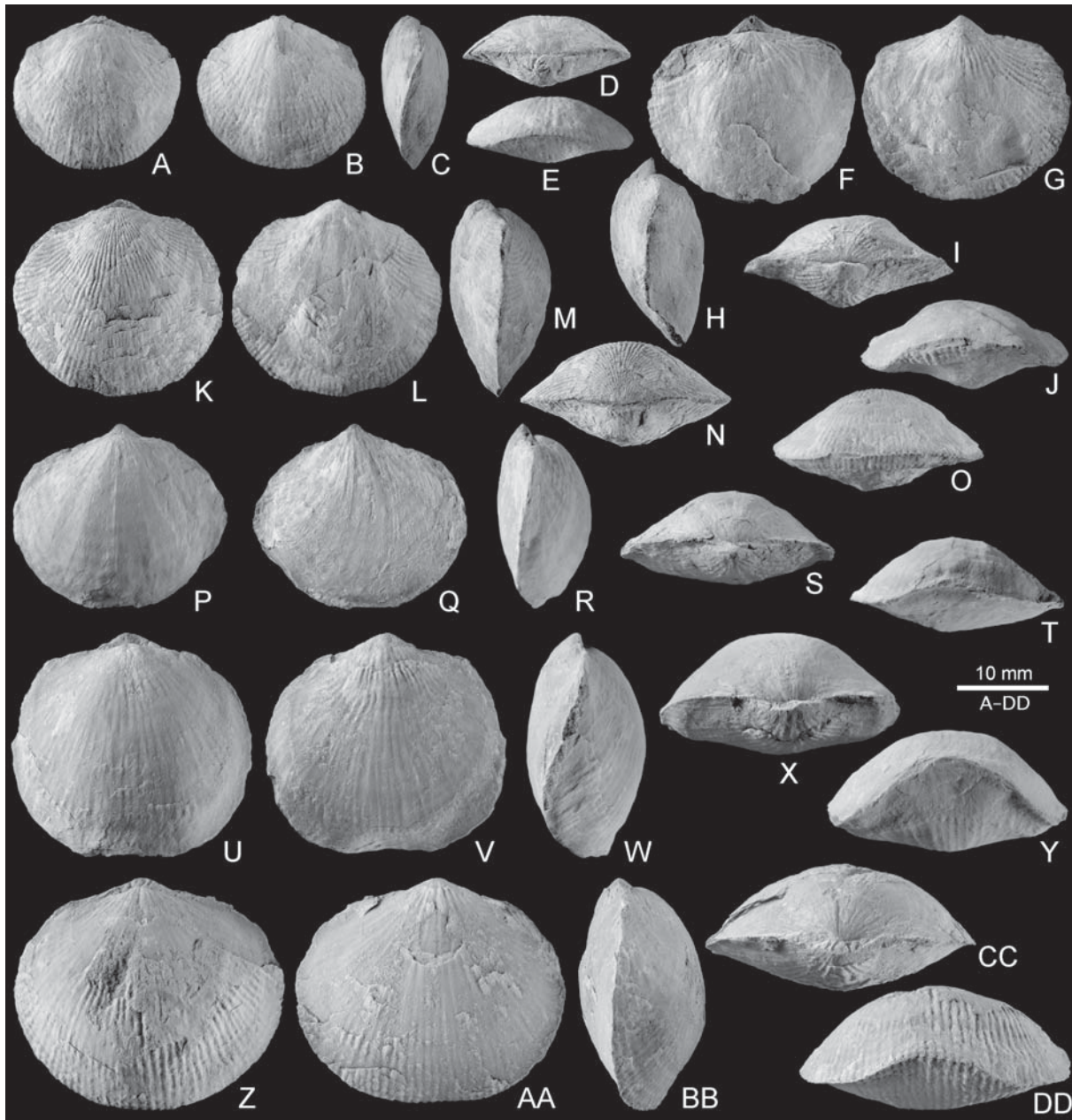


Text-fig. 6. Distribution of brachiopod shells within the coquina bed. A-C – orientation of shells and geopetal indicators (red line – position of line perpendicular to the geopetal surface) in particular fragments of slab; n – number of shell orientation measurements; n_{geo} – number of geopetal structures; $Av.$ – average position of the line vertical to the geopetal surface; S_d – standard deviation of geopetal surface measurements

160–180°. In the lowermost part C the orientation of the shells is more scattered and only 38% of them are located in these intervals. A significant number of shells oriented perpendicularly to the reference level was also observed in this part.

Because the brachiopod shells are mostly uncrushed or non-disarticulated, they usually serve as geopetal indicators; their orientation is presented as

the position of a line perpendicular to the boundary between the internal sediment within the shell and the infilling cement. In parts A and B, the position of this line is identical (averagely 93°), whereas in part C it is slightly larger (106°). Although in the case of these measurements the standard deviation is relatively large, they indicate that the geopetal structures are generally parallel to the longer axis of the shells.

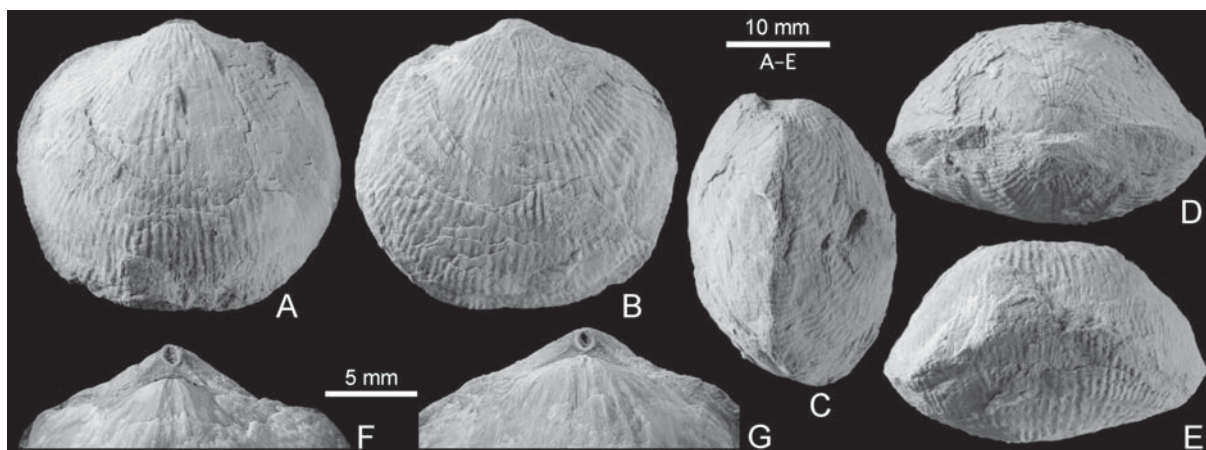


Text-fig. 7. The arypide *Desquamatia globosa jozefkae* Baliński subsp. nov. from Józefka Quarry. A-E, F-J, K-O, P-T, U-Y, Z-DD – six articulated shells ZPAL Bp 81/2, ZPAL Bp 81/17, ZPAL Bp 81/3–5 and ZPAL Bp 81/1 (holotype) in dorsal, ventral, lateral, posterior, and anterior views, respectively

The occurrence of a completely opposite position of geopetal structures (cement in the lower part of the shell) is sporadic and a few specimens displaying this property (not illustrated in Text-fig. 6) are found only in part C.

The infillings of brachiopod shells strongly vary even among neighbouring shells (see Text-figs 10B,

C, E; 11C) and are different from the coquina matrix. These differences are visible even in macroscopic view: the infilling of shells is usually light grey whereas the matrix is dark grey or black (Text-fig. 10). In microscopic view the material within the shells represents three microfacies: bioclastic MF composed of crinoidal debris (Text-fig. 10B), peloidal/micritic



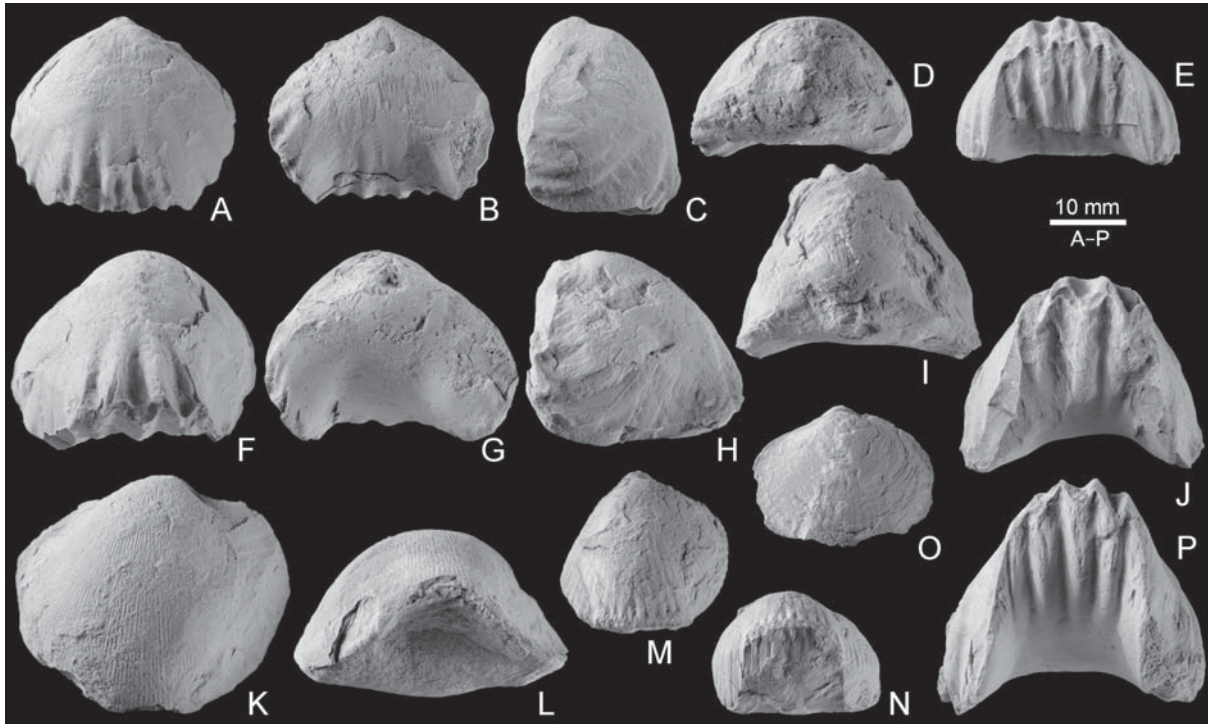
Text-fig. 8. The atrypide *Desquamatia globosa jozefkae* Baliński subsp. nov. from Józefka Quarry. A-E – articulated shell ZPAL Bp 81/7 in dorsal, ventral, lateral, posterior, and anterior views. F, G – dorsal view of posterior region of two shells ZPAL Bp 81/6 and ZPAL Bp 81/8, respectively, showing ventral interarea and pedicle opening

MF (Text-fig. 10D), and dolosparitic MF (Text-fig. 10A, B). The presence of dolomite in the investigated brachiopod coquina bed is a common feature, but the process of dolomitisation was multistage and differed spatially. Generally, its first stage corresponds to the formation of a completely dolomitised infilling of brachiopod shells (Text-fig. 10A), which were later transported and deposited within a bioclastic matrix that is not dolomitised. The second stage of the process took place after the formation of the entire succession, and its expression is partial dolomitisation of the coquina matrix together with the material infilling the brachiopod shells. Thereby, the shells without traces of dolomitisation, which are situated within the dolomitised matrix (Text-fig. 10E), were infilled by primary micritic material, lithified enough and isolated from the surrounding sediment, so that the dolomitization process was impossible or limited. A similar process of late dolomitization is known in a larger scale from several Devonian successions, e.g., that observed in the Skały section succession in the northern part of the Holy Cross Mountains (Skompski and Szulczewski 1994), where dolomicritic layers are preserved in primary form within a succession of coarse-grained epigenetic dolosparites.

ORIGIN OF BRACHIOPOD MASS OCCURRENCES

Brachiopod mass occurrences as densely packed coquinas generally have three possible interpreta-

tions: (i) autochthonous/parautochthonous occurrences, controlled by ecological and sedimentological factors, with accumulation of specimens in their life place or its direct neighbourhood, (ii) autochthonous occurrences, usually stimulated by cold-seep activity, and (iii) allochthonous occurrences, controlled by sedimentological processes, with transport of specimens far from their life places. In the first case, recorded by most of the brachiopod shell concentrations, the final sedimentary record is the effect of reciprocal relation of 3 factors: bioproduction, rate of shell disintegration and rates of net sedimentation (Kidwell 1986; Kidwell *et al.* 1986; Tomašových *et al.* 2006). However, it should be emphasised that the models presented in the cited papers refer mostly to the autochthonous/parautochthonous concentrations (“i”). In specific conditions, Ceno-/Mesozoic brachiopods are able to form very thick *in situ* concentrations despite a relatively low carbonate production (see examples and thorough discussion of the problem in: Tomašových *et al.* 2006; Reolid *et al.* 2012; Tomašových and Kidwell 2017). More often brachiopods occur, especially in the Palaeozoic, as a dominating element in beds with thicknesses of several to several tens of centimetres. Such types of coquinas have been described from Silurian and Middle Devonian strata (*Pentamerus* layers of Johnson 1989; *Bornhardtina* layer described by Biernat 1953; Hladil 1983; Skompski and Szulczewski 1994). In these cases the rapid growth of the brachiopod population was stimulated by the post-storm “fertilization” of the sea floor. Similar atrypid-dominated



Text-fig. 9. Orthide and rhynchonellide brachiopods from Józefka Quarry. **A-J, P** – *Coeloterorhynchus dillanus* (Schmidt, 1941). **A-E** and **F-J** – two articulated shells ZPAL Bp 81/9 and ZPAL Bp 81/10, respectively, in dorsal, ventral, lateral, posterior, and anterior views. **P** – anterior view of shell ZPAL Bp 81/11. **K, L** – *Schizophoria schnuri prohibita* Halamski, 2012; dorsal and anterior view of a complete, slightly deformed shell ZPAL Bp 81/12a. **M, N** – *Hypothyridina* sp.; incomplete shell ZPAL Bp 81/13a in dorsal and anterior views. **O** – *Phlogoiderhynchus polonicus* (Roemer, 1866); subadult, decorticated shell ZPAL Bp 81/14 in dorsal view

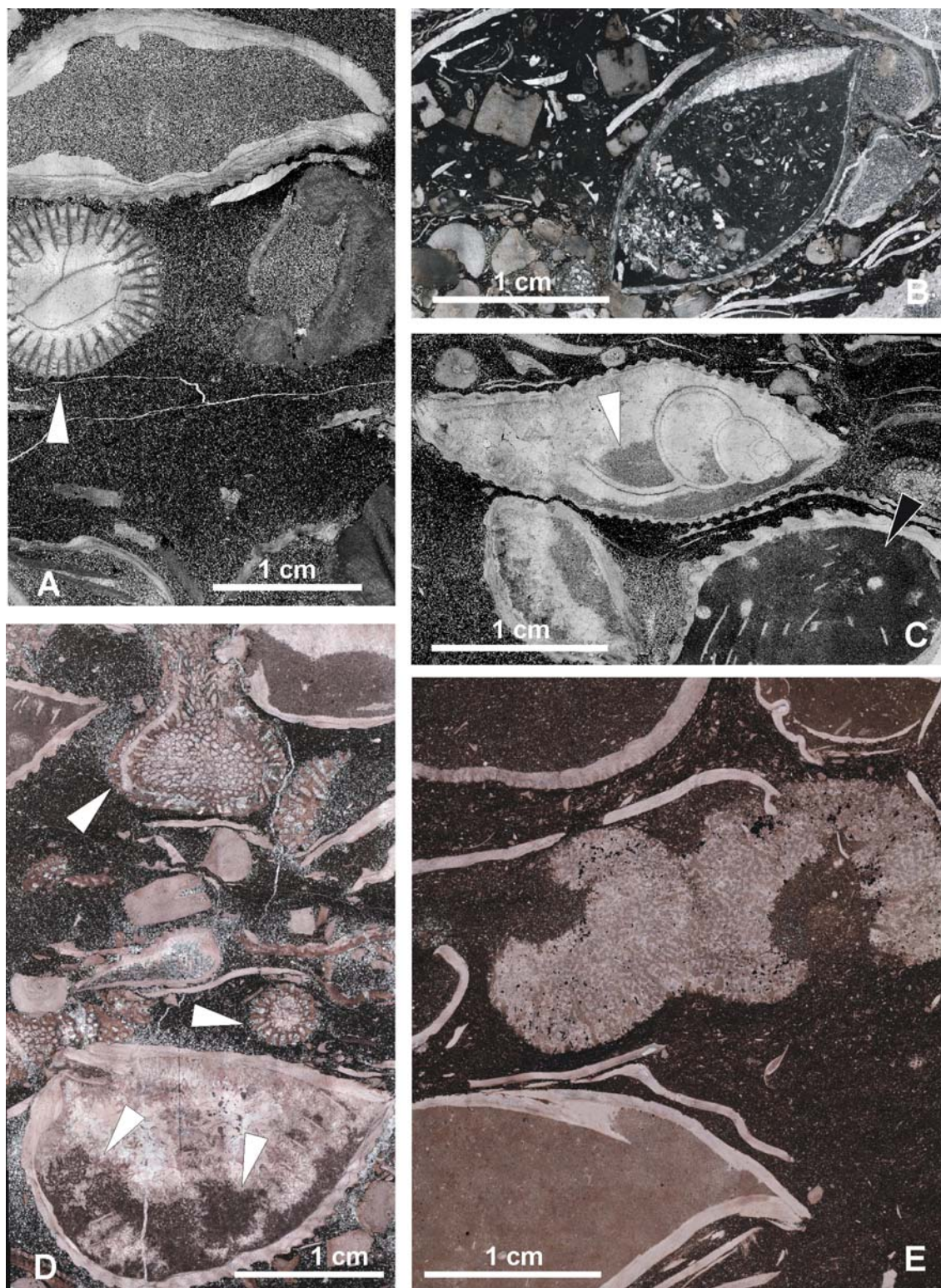
deposits (mainly *Desquamatia globosa*) from the Middle Devonian of the Holy Cross Mountains and the Cracow area have been analysed by Racki and Baliński (1981) and Racki (1993a). A significant feature of these occurrences was the co-existence of brachiopods with crinoids and the relative scarcity of fauna typical of shallow Middle Devonian seas, i.e., massive stromatoporoids, amphiporoids and tabulates. According to the papers cited above, the sedimentary environment of the investigated deposits has been interpreted as poorly aerated intershoal areas or restricted lagoons with fluctuating or even lowering salinity. Regarding the superficial similarity of the brachiopod beds described by Racki and Baliński (1981) to those described in the present paper, the principal difference is the level of brachiopod packing, evidently more dense in the Józefka succession, and the location of the brachiopod bed from Józefka in a basinal rather than a shallow-water succession.

Comparison of the brachiopod beds investigated here not only with Palaeozoic but also Mesozoic and Cenozoic brachiopod shell concentrations (Taddei

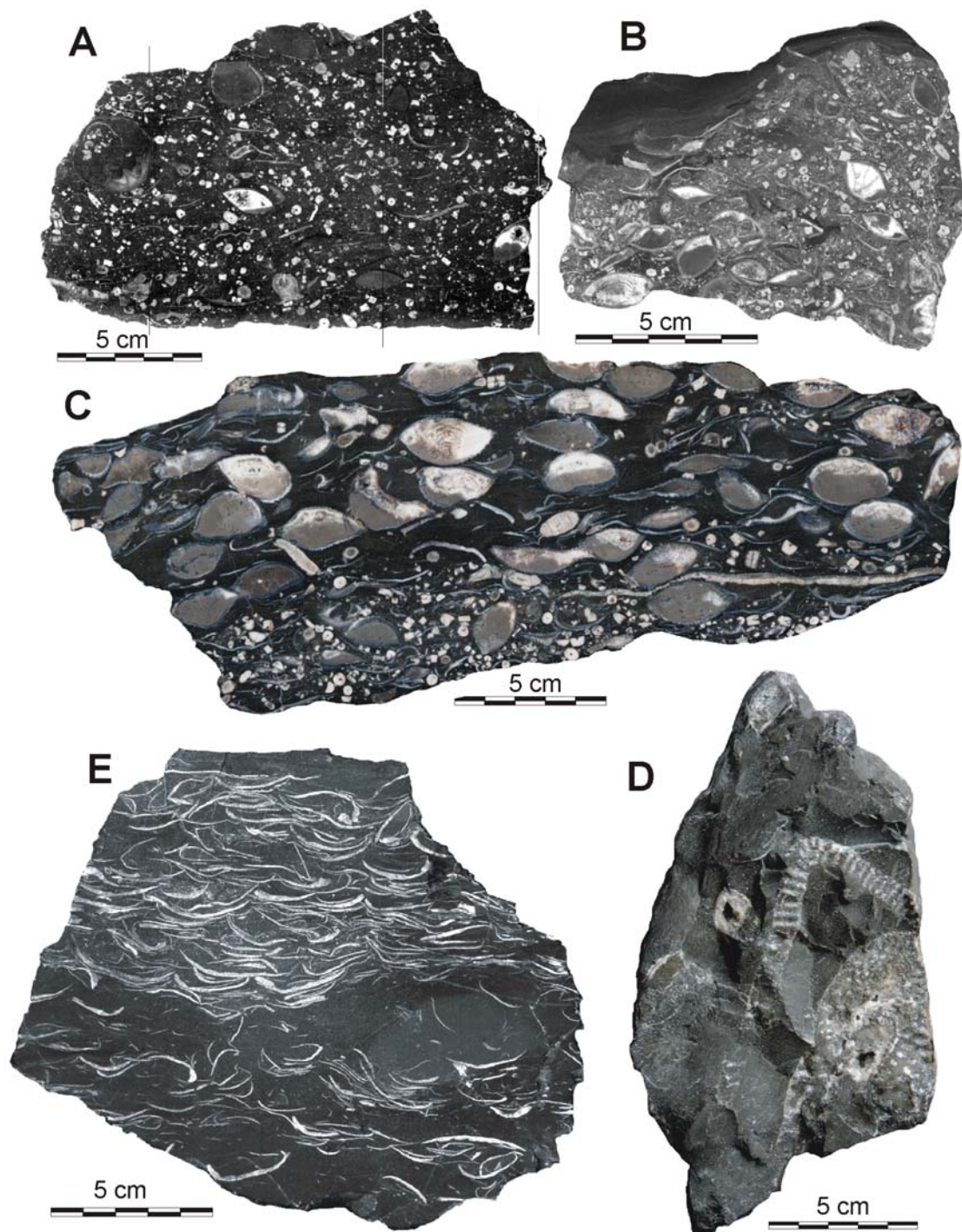
Ruggiero 1994 with references; Reolid *et al.* 2012) indicates difficulties in finding direct analogies. An analogous situation is related to the largest occurrence of facies composed of redeposited brachiopods mixed with crinoids – the Jurassic Hierlatz facies of the Calcareous Alps and Carpathians (Bernoulli and Jenkyns 1974). This facies overlies Triassic carbonate platforms or infills large-scale (up to 10 m wide) neptunian dykes. According to Vörös (1986, 1991) and Uchman and Tchoumatchenko (1994), brachiopods and crinoids, which compose the dominating component of the Hierlatz limestones, were redeposited from seamount tops, where they lived at moderate water depths.

In the succession quoted above, the brachiopods are markedly dominating, but the beds cannot be classified as densely packed coquinas, because the brachiopods are usually more or less scattered within a detrital matrix. The shape of the brachiopod limestone bodies is either unknown or they form long horizontal layers.

In that respect, a “brachiopod nest” most similar



Text-fig. 10. Examples of microfacies from the brachiopod coquina bed. A – atrypid shell completely filled with dolomitic crystals, single rugose coral is arrowed; matrix partly dolomitized, B – atrypid shell filled with bioclastic material; two different stages of geopetal structures are visible; C – shells with different types of infilling material: bioclastic (black arrow) and micritic (white arrow); D – concentrations of bryozoan *Canutrypa francqana* Bassler, 1952 (white arrows) detritus within brachiopod coquina; peloidal/micritic infilling of shell is visible (arrowed); E – fragment of lithistid demosponge within brachiopod coquina; notice different infilling of brachiopod shell and coquina matrix



Text-fig. 11. A-D – fragments of brachiopod coquina bed, dominated by crinoids (A), dominated by brachiopod shells (C), transition between coquina bed and surrounding deposit without brachiopods (B), receptaculid fragments within coquina bed (D); E – coquina composed of disarticulated shells from the section illustrated in Text-fig. 5B

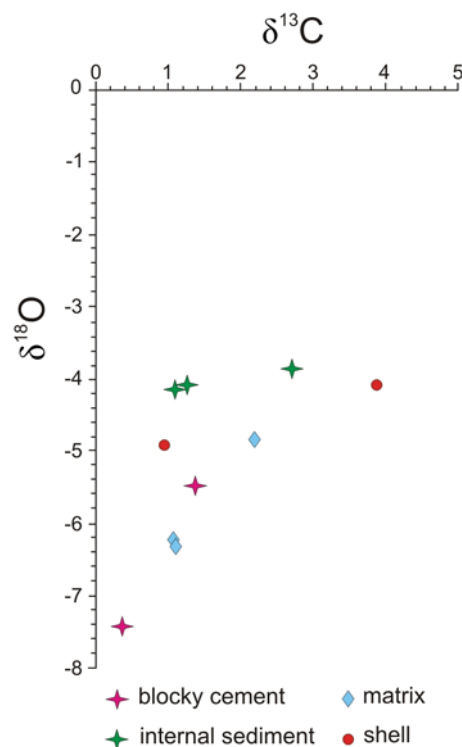
to the studied brachiopod coquina bed is known from the intensively investigated Moroccan sites: the upper Silurian *Septatrypa* Mound (Ager *et al.* 1976) and

the Devonian Aferdou El Mrakib reef/mound in the eastern Anti-Atlas (Kaufmann 1998, Tessitore *et al.* 2013). The brachiopod assemblage described from the

second locality is dominated by the atrypide *Kerpina vineta* Struve, 1961 and the pentameride *Ivdelinia pulchra* Franchi, Schemm-Gregory and Klug, 2012 (Halamski and Baliński 2013). The brachiopods are extremely densely packed, the shells are usually uncrushed and non-disarticulated. The thickness of the bed is extremely large (several metres), but the sedimentological and facies characteristics of this coquina have not been recognised to date. Kaufmann (1998) interpreted the lens of brachiopods as deposited *in situ* and, based on the comparison with other reef-dwelling faunas (Godefroid and Racki 1990), attributed these brachiopods to semi-protected, intermittently agitated habitats. Franchi *et al.* (2012) suggested that the brachiopod assemblage lived there during an earlier stage of reef development, although it is not connected with any traditional reef guild. Compared to the Józefka coquina, the most significant difference is the nearly complete absence of crinoids in the Aferdou El Mrakib mound and the location of the brachiopod coquina in its direct proximity, not in the basinal facies.

Concerning model “ii” (concentrations stimulated by cold-seep activity), the Silurian *Septatrypa* Mound (Ager *et al.* 1976) is the best example of densely packed brachiopod coquinas of large thickness, composed of articulated shells and interpreted as the effect of a chemosynthetic process, stimulated by fluid seepage. An exceptional feature of this succession is the intercalation of the brachiopod coquina with microbial stromatolitic layers (Ager *et al.* 1976). This remarkable attribute of the mound resulted in an interpretation of the sedimentary environment as an isolated shoal within a muddy basin. Following more detailed investigations (Barbieri *et al.* 2004, p. 537) there are three features, which induce the hypothesis about the contribution of hydrocarbon seepage in the formation of the brachiopod concentration: “... (1) the presence of a dense faunal assemblage surrounded by faunally poor siliciclastic deposits, which is (2) embedded in carbonate deposits, and (3) is monospecific ...”. Buggisch and Krumm (2005) and Jakubowicz *et al.* (2017, 2018) have confirmed the seep-nature origin of the discussed mound based on isotope analysis.

All circumstances quoted by Barbieri *et al.* (2004) have been more or less fulfilled in the case of the Józefka coquina bed; moreover, the Szydłówek Beds are saturated by hydrocarbons to an exceptionally high degree compared to other units of the Devonian in the Kostomłoty facies zone. The possibility of the formation of the Józefka brachiopod coquina bed as a seep-induced assemblage has been seriously considered in the beginning of our investigations,



Text-fig. 12. Carbon vs. oxygen isotope cross-plots for various carbonate phases found in the brachiopod coquina bed. All results are in ‰ V-PDB

but it was definitely excluded after the analysis of the isotopic composition of the shells, matrix and cements (Text-fig. 12). The isotopic measurements are generally in accordance with the marine signals typical of the Givetian/Frasnian transition (Buggisch and Joachimski 2006). In comparison to other examples of seep carbonates (Buggisch and Krumm 2005; Paull *et al.* 2007; Jakubowicz *et al.* 2015 with references), the carbon isotope values seem to be too high (from 0.39 to 3.94‰_{PDB}). Moreover, it is necessary to add that other features expected in the case of seep deposits (tube worms, microbial fabrics, specific fibrous cements, sulphide-sulphate mineral deposits, etc.; for discussion see e.g., Campbell and Bottjer 1995; Jakubowicz *et al.* 2017) were not observed here.

ORIGIN OF THE JÓZEFKA BRACHIOPOD COQUINA BED

The review of the different hypotheses on the nature of brachiopod coquinas presented above shows that it is difficult to find an exact analogy for the Józefka brachiopod accumulation. However, it seems

that in this case gravitational transport of the brachiopod shells to a deeper basin is the most plausible explanation. There are five basic arguments pointing to this hypothesis: (1) massive lithology and palaeontological contrast between the coquina and the surrounding deposits; (2) high diversification of the internal sediment within the shells, different than the coquina matrix; (3) a lens-shape geometry of the brachiopod unit in a cross-section perpendicular to the bedding dip; (4) complex internal stratification; and (5) preferred orientation of the brachiopod shells. Each of these arguments treated separately could be also explained in terms of autochthonous growth of the brachiopod concentration. For example, the lens-shape geometry of the brachiopod body may be typical of a biogenic mound. However, we have observed only one specific cross-section of the coquina bed and therefore on this basis its difficult to forejudge the mound shape geometry of the entire bed. Differences in the type of sediment preserved within the shells could be explained as a diagenetic feature, especially the abundance of dolomite crystals. On the other hand, the differences of infilling of brachiopod shells (micritic or bioclastic) have a simpler explanation in the different primary location of the shells than in a later infill during storms and burial processes.

It seems that the composite treatment of the arguments presented above caused that the hypothesis of an allochthonous accumulation of the brachiopods is most reasonable. The bioclastic material (brachiopod shells mixed with crinoidal debris) was transported as low-velocity, high-density, gravity-induced debris flows. The specific feature of the investigated coquina is the high contribution of articulated shells. Most probably this fact indicates rapid burial of the brachiopod assemblage. On the other hand, dense packing of the shells caused their parallel orientation. Some shells were empty during transport or were only partially infilled with an internal sediment, which is proved by the post-sedimentary parallel orientation of the geopetal indicators. It is obvious that even in the case of gravitational transport, the brachiopod shell material should be preliminary concentrated in the initial site of brachiopod growth, located not far from the place of final deposition. As it is discussed in the next chapter, the most probable location of the original growth place of the brachiopod population was a submarine high to the north of the Józefka area. The nature of this initial concentration and the reasons of the assumed high brachiopod productivity remains unknown. The subsequent relative enrichment of the flowing bioclastic material was probably connected with the winnowing of mud during trans-

portation. All specimens of brachiopods have been obtained from hard limestone, which means that the lack of small specimens may be regarded as a sampling bias. It seems that an analogical – to some respect – process was observed in another lens-shaped bioclastic unit in the Palaeozoic of the Holy Cross Mountains – the lower Carboniferous limestones near Gałęzice (Bełka and Skompski 1988; Bełka et al. 1996). In that case the crinoidal-brachiopod material was transported in a similar way, but on a longer distance and generally larger scale, which is recorded in the evidently greater thickness of the limestone unit, located within the basinal Culm shales.

A more evident sedimentological analogy to the Józefka brachiopod bed has been described by Biernat and Szulczewski (1993). The brachiopod *Zilimia polonica* assemblage, together with numerous crinoids, has been deposited as nearly 0.5 m thick intercalation within the Famennian marly limestones and shale complex deposited in the intra-shelf basin. The authors gave numerous arguments for a sediment gravity flow mechanism as the decisive factor of the deposition.

On the other hand, the interpretation of some features observed in the Józefka brachiopod coquina bed are not as obvious and require a more detailed explanation:

(1) *Preservation of non-disarticulated shells.* Highly dynamic transport of biogenic material usually causes disintegration and crushing of shells. As documented by the large block illustrated in Text-fig. 6, the layers of non-disarticulated specimens (intervals A and C) are separated by flattened shells (interval B). This indicates that transport of bioclastic material was performed in several phases and the final sedimentary effect was caused by the type of original biogenic material.

(2) *Lack of an erosional boundary in the sole of the coquina bed.* The presence of an erosional boundary in the sole of gravity flow deposits is commonly expected. Such boundaries are widely observed in the slightly younger Kostomłoty Beds in the nearby Górnio Quarry (Szulczewski 1968). In the case of the atrypid coquina bed at Józefka, the sole boundary is distinct but not erosional in nature. Most probably this is the result of the low cohesiveness of the muddy bottom, which was an effect of the marly composition of the bottom deposits.

(3) *Large thickness and massive structure of the coquina bed.* The thickness of the investigated coquina bed is several times larger than the average bed thickness in the investigated succession. Almost certainly the deposition of the coquina bed was an effect of multiple flows and gradual sinking of the

deposited portions of sediment. In this regard, the lower crinoidal layer from the block illustrated in Text-fig. 6 may be treated as a model of this process. Thickness increase of this crinoidal layer is probably caused by blocking of the flow of bioclastic material and sinking of the stacking deposits, similarly to load deformation of crinoidal marls, observed e.g., by Biernat and Szulczewski (1993) in the lower Famennian of Psie Górki hills (central part of the Holy Cross Mountains). Such structures are well known from deep marly sea beds, as well as from shallow carbonate platforms. In the final stage of their development they may form a large isolated “drop” of clastic material within marly deposits. Dżułyński and Kubicz (1975) recognised such process in a succession of perfectly outcropped, densely packed brachiopod “drops” within Muschelkalk marly limestones (Middle Triassic) of Upper Silesia (southern Poland). The thickness (diameter) of several structures exceeds 1 m; some fragments sank into other shell accumulations. The boundaries of shell concentrations are completely irregular, which was caused by the nature of unstable density stratification. According to Dżułyński and Kubicz (1975), the general cause of such deformation was storm-induced redeposition. Although in the case of the Józefka coquina bed, another triggering mechanism of redeposition is proposed (not storms but rather earthquakes), the general process leading to thickness increase seems to be identical in both cases. To some extent a sinking mechanism is also responsible for the lack of an erosional boundary in the sole of the coquina bed.

SOURCE AREA OF THE BIOCLASTIC MATERIAL

It is rather difficult to estimate the ecological requirements of the fauna composing the assemblage recognised within the coquina bed. As stated above, the significance of crinoids, bryzoans, sponges and receptaculitids in such analysis is relatively low; more important are data provided by brachiopods and – to some respect – conodonts. The two dominant brachiopod species of the assemblage represent groups, which possessed a very efficient, spirally coiled lophophore (spirolophe). This kind of lophophore provided a large surface for capturing food particles and maximizing respiration (Fürsich and Hurst 1974; Vogel 1975; Copper 1986). Thus, *D. globosa jozefkae* and *C. dillanus* might be well adapted to deeper water settings characterised by a lower nutrient concentration. Efficiency of the lophophore was probably further

enhanced by the deflection of the anterior commissure (uniplication), which enabled these brachiopods to separate inhalant and exhalant water currents. This was especially evident in *C. dillanus*, which possessed a very long, dorsally directed ventral tongue. It is usually accepted that in brachiopods having spirally coiled brachia and uniplicate shells, the nutrient-rich inhalant water current flew from the sides of the shell through the apices of spiral cones, whereas the exhalant current removed waste products anteriorly through the dorsal median fold (Copper 1986; Emig 1992; Williams *et al.* 1997; Halamski and Baliński 2009). Although the spirolophous lophophore and deflection of the anterior commissure may occur in forms inhabiting various water depths, they are particularly advantageous adaptations for forms dwelling in deeper, quiet and/or nutrient-poor settings.

Shells of *D. globosa jozefkae* have a distinct ventral interarea and a pedicle opening (Text-fig. 8F, G) suggesting that they retained a functional pedicle throughout their whole life. They were attached to hard substrates (e.g., other shells of dead or living co-occurring brachiopods) by their pedicle, but probably partially supported part of their weight by resting on the sea floor. *Coeloterorhynchus dillanus*, subordinate in the assemblage, was also most probably attached by its pedicle in the early stages of growth, but later, in result of progressive curvature of the ventral beak, which was pressed against the apex of the dorsal valve, the pedicle most probably atrophied and the shells freely lay on the sea floor.

Conodonts accompanying the brachiopod shell accumulation constitute a low diversity association, with polygnathids highly prevailing over icriodids. Among polygnathids predominate lanceolate, narrow-platform [P₁] elements. Such conodont association is typical of the Szydłówek Beds. It represents the polygnathid–icriodid biofacies (Racki 1985; Racki and Bultynck 1993), one of the globally distributed biofacies distinguished by Sandberg *et al.* (1989) in the Middle and Upper Devonian.

As summarized by K. Narkiewicz and Bultynck (2007, p. 422), the narrow-platform representatives of *Polygnathus* display a much wider range of distribution over the shelf areas than the polygnathid–icriodid biofacies. However, a specific feature of this biofacies in the stratigraphic interval containing the studied shell accumulation, is also the lack of broad-platform conodonts, especially *Klapperina*, *Mesotaxis* and *Ancyrodella*, which contemporaneously occupied deeper, pelagic environments.

Generally, the distribution of conodont biofacies was controlled by regional palaeotectonic set-

tings, water depth, and distance from the shoreline (Sandberg *et al.* 1989; Ziegler and Sandberg 1990, p. 14). According to Racki and Bultynck (1993, p. 19), the elimination of broad-platform forms in the Szydłówek Beds was caused by ecological factors within a semi-closed intrashelf basin, with mostly stagnant and oxygen-stratified water. However, the same biofacies was identified by K. Narkiewicz and Bultynck (2010) in a similar stratigraphic position in the Lublin area, where it is situated within deeper shelf facies, and the influence of these causes on the conodont distribution does not seem obvious.

The anatomical analysis of the dominating brachiopod species presented above points to a relatively deep area for brachiopod growth and susceptibility of the brachiopod shells to transportation. According to the location of the Józefka area in the palaeogeographic pattern of the Holy Cross Mountains there are two possible places, where such requirements could be fulfilled. The first one was situated on the slope of the central carbonate platform (“Dyminy Reef” area) stretching to the south-west of present-day Józefka Hill. The assemblage of brachiopods, crinoids and bryozoans could develop on the limited area of the slope, relatively deeper than the assemblage of stromatoporoids, amphiporids and tabulates, i.e., a typical fauna of the shallow water Givetian/Frasnian carbonate platform. However, as indicated by the presence of a thick, massive layer (Text-fig. 3, bed X) recognised above the coquina bed, the non-disarticulated brachiopods and shallow water material (stromatoporoids, tabulates, rugose corals, amphiporoids) were transported separately. Independently of the mechanism triggering the redeposition of bioclasts – storms, earthquakes – the debris flow deposits on the bottom of the basin should be composed of material derived from both zones of primary deposition.

Therefore the second hypothesis, assuming transportation of brachiopods and associated components from another direction, not related to the slope of the carbonate platform, seems more probable. Such possibility may be supported by the existence of a local elevation to the north of present-day Górnio village (see Text-fig. 1B). The presence of such elevation was postulated by Baliński *et al.* 2016 (after data presented by Małkowski 1981) based on the regional distribution of coarse-grained material within the Kostomłoty Beds. North-south transportation directions in this area were postulated also in the early papers of Szulczewski (1968, 1971). Baliński *et al.* (2016) discussed such possibility in the context of allochthonous material in a parautochthonous brachiopod assemblage reported from another section

of Józefka Quarry. It seems that the Górnio elevation (a submarine sea-mount), located at several kilometres from the shallows of the central platform, could function as a growth place of the studied brachiopod-crinoid population. It also explains the relative abundance of fistuliporid bryozoans, in contrast to the moderate frequency of these fossils in other areas of the Holy Cross Mts, especially in “Dyminy Reef” area.

It should be noted here that in the investigated section appeared also several thin (several centimetre thick) intercalations of brachiopod coquinas, composed of disarticulated shells, with an erosional sole, graded bedding of biotrititic parts, and lamination in the topmost part of the layer (compare Text-figs 3B and 11E). This type of coquinas, completely different in each feature from the thick bed described in this paper, was interpreted by Vierek (2008) as deposits reworked by storms. Regardless the correctness of this interpretation it can be assumed that the triggering mechanism of gravitational transport of the articulated shells proposed here seems to be connected with seismic disturbances rather than with storms. In the case of storms and other high-energy hydrodynamic events, the material from different shallow zones should be mixed together. The investigated section indicates separation of sources of bioclastic material, which points to local, probably tectonic reasons of the mass flow movements.

SYSTEMATIC PALAEOONTOLOGY

(A. Baliński)

The brachiopod material described in the present paper is deposited in the Institute of Palaeobiology of the Polish Academy of Sciences in Warsaw under collection number ZPAL Bp 81.

Order Orthida Schuchert and Cooper, 1932

Suborder Dalmanellidina Moore, 1952

Superfamily Enteletoidea Waagen, 1884

Family Schizophoriidae Schuchert and LeVene, 1929

Genus *Schizophoria* King, 1850

TYPE SPECIES: *Conchylolithes Anomites resupinatus* Martin, 1809; lower Carboniferous; Derbyshire, England, United Kingdom.

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

TYPE SPECIES: as for the genus.

Schizophoria (S.) schnuri prohibita Halamski, 2012
(Text-fig. 9K, L)

2012. *Schizophoria (Schizophoria) schnuri prohibita* ssp. n.; Halamski, pp. 356–359, figs 4A–C, E, M, Q, V–Y, BB–EE, 7A–II, 8C, E.

2016. *Schizophoria schnuri prohibita* Halamski, 2012; Halamski in Baliński *et al.*, p. 145, pl. 10, figs 21, 22.

MATERIAL: Three complete to nearly complete shells and six broken dorsal valves. Dimension of the most complete specimen (in mm): length 31.9, width 35.7, thickness 20.0.

REMARKS: This subspecies was originally described in detail by Halamski (2012) from the same quarry as the presented material. It is noteworthy, however, that the holotype and stratotypic paratypes described by that author come from slightly younger layers exposed in the eastern wall of Józefka Quarry. More recently the subspecies was described from the same quarry and the nearby road-cut by Halamski (in Baliński *et al.* 2016) from layers representing the Szydłówek and Wietrznia beds (late Givetian to early Frasnian).

The present material is identical externally with the type material of the subspecies. One of the investigated dorsal valves shows a wide dorsal muscle field characteristic of the taxon.

Order Rhynchonellida Kuhn, 1949

Superfamily Uncinuloidea Rzhonsnitskaya, 1956

Family Hypothyridinidae Rzhonsnitskaya, 1956

Genus *Hypothyridina* Buckman, 1906

TYPE SPECIES: *Atrypa cuboides* Sowerby, 1840; Givetian, United Kingdom.

Hypothyridina sp.
(Text-fig. 9M, N)

MATERIAL: Five fragmentary shells.

REMARKS: The described specimens can be attributed to the genus *Hypothyridina* on the basis of their cuboidal shape, high and flat to weakly convex tongue and characteristic radial costae. However, the present material is too incomplete to be reliably attributed to a species.

Superfamily Camarotoechioidea Schuchert, 1929
Family Septalariidae Havlíček, 1960

Genus *Phlogoiderhynchus* Sartenaer, 1970

TYPE SPECIES: *Uncinulus arefactus* Veevers, 1959; lower Frasnian, Upper Devonian; Australia.

Phlogoiderhynchus polonicus (Roemer, 1866)
(Text-fig. 9O)

1866. *Camarotoechia? polonica*; Roemer, p. 676, pl. 13, figs 9, 10.

2016. *Phlogoiderhynchus polonicus* (Roemer, 1866); Baliński in Baliński *et al.*, p. 147, pl. 11, figs 1–5 (with synonymy).

MATERIAL: One subcomplete, strongly decorticated shell. Dimensions (in mm): length 19.2, width 24.0, thickness 11.4.

REMARKS: This species was recently described from Józefka and Radlin by Baliński (in Baliński *et al.* 2016 with detailed location of Radlin outcrops). Earlier, Biernat and Szulczewski (1975) revised the species and gave a detailed description of its morphology, internal structure and the range of intraspecific variability. The single available subadult shell fully agrees with the characteristics of *P. polonicus* described by Biernat and Szulczewski (1975).

Superfamily Pugnacoidea Rzhonsnitskaya, 1956

Family Pugnacidae Rzhonsnitskaya, 1956

Genus *Coeloterorhynchus* Sartenaer, 1966

TYPE SPECIES: *Coeloterorhynchus tabasensis* Sartenaer, 1966; middle and upper Frasnian, Iran.

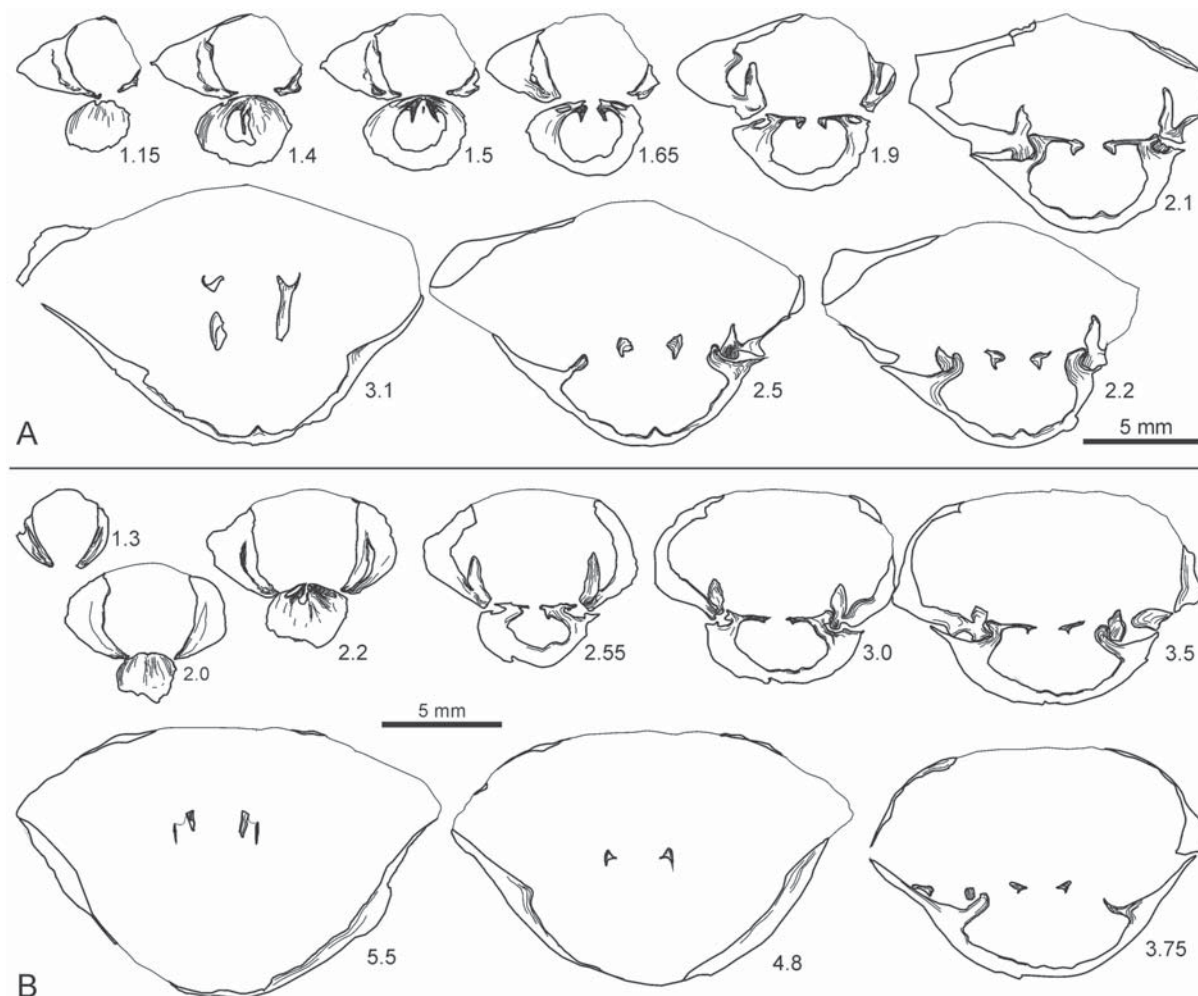
Coeloterorhynchus dillanus (Schmidt, 1941)
(Text-figs 9A–J, P; 13)

1941. *Pugnax acuminatus dillanus* n. subsp.; Schmidt, pp. 284, 285, pl. 1, figs 2–4.

2016. *Coeloterorhynchus dillanus* (Schmidt, 1941); Baliński in Baliński *et al.*, pp. 147–149, text-figs 9, 10, pl. 11, figs 6–30, 32 (with synonymy).

MATERIAL: 26 complete to almost complete shells and 38 fragmentary specimens. Dimensions of three illustrated specimens (in mm), respectively: length 23.7, 25.6, 27.2, width 30.0, 32.5, 35.3, thickness 19.0, 24.7, 29.6.

REMARKS: This species was recently described in



Text-fig. 13. Transverse serial sections of *Coeloterorhynchus dillanus* (Schmidt, 1941) through two shells ZPAL Bp 81/15 (A) and ZPAL Bp 81/16 (B) from Józefka Quarry. Numbers refer to distances in mm from the tip of the ventral umbo

details from the eastern wall of the Józefka Quarry and from the nearby road-cut by Baliński (in Baliński *et al.* 2016). Earlier, it was also described from the Wietrznia Beds of the Wietrznia Quarry (Baliński 2006). Detailed occurrences of the species were given by Baliński (in Baliński *et al.* 2016, pp. 148, 149).

Order Atrypida Rzhonsnitskaya, 1960
 Family Atrypidae Gill, 1871
 Genus *Desquamatia* Alekseeva, 1960

TYPE SPECIES: *Atrypa (Desquamatia) khavae* Alekseeva, 1960; lower Eifelian, Middle Devonian; Urals, Russia.

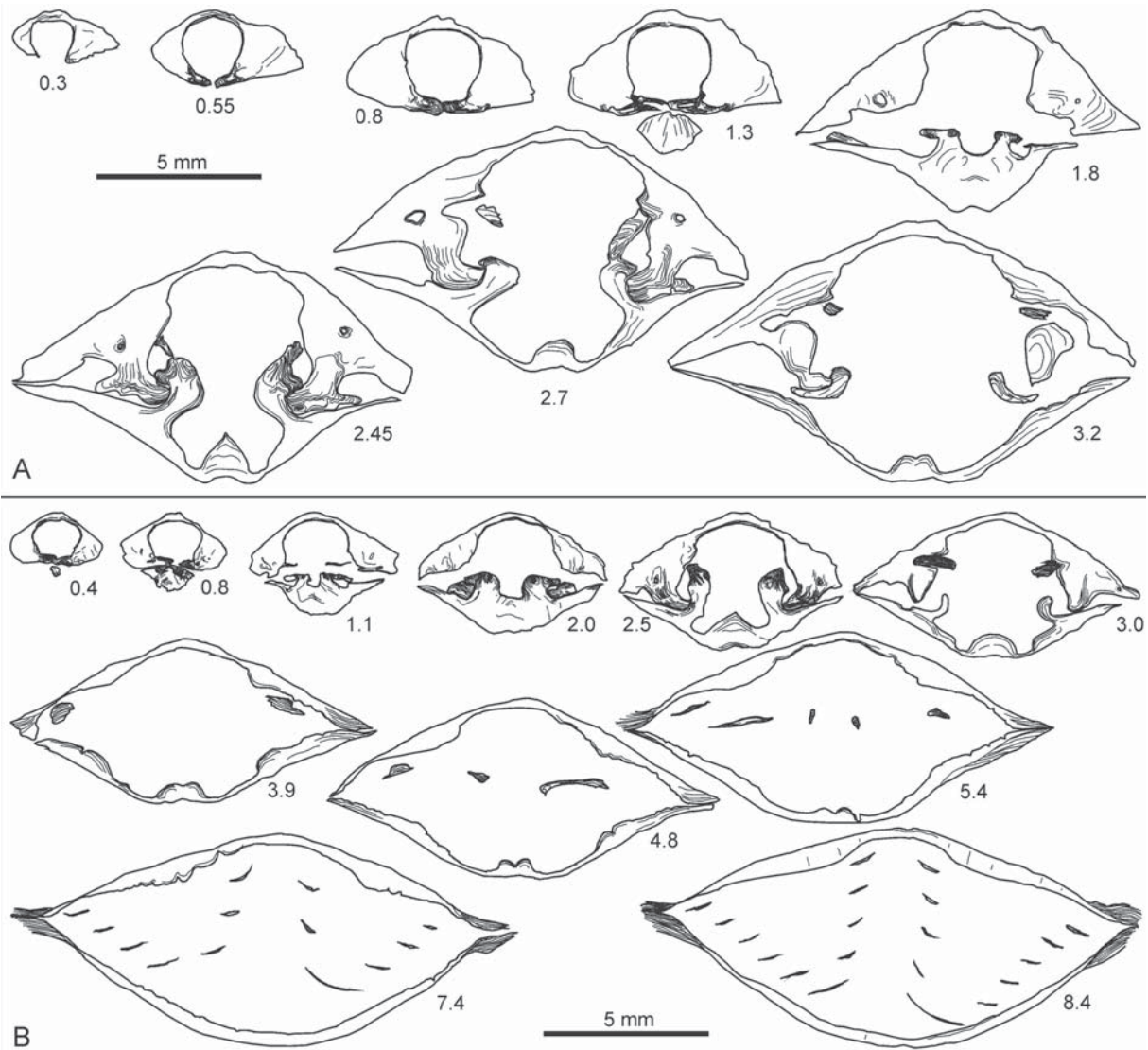
Desquamatia globosa (Gürich, 1896)
Desquamatia globosa jozefkae Baliński subsp. nov.
 (Text-figs 7, 8, 14, 15)

TYPE MATERIAL: Holotype (a complete articulated shell) ZPAL Bp 81/1 (Fig. 11 = 7Z-DD), 154 complete and 56 fragmentary shells, collection number ZPAL Bp 81/2-8, 17-19, 23-25.

TYPE LOCALITY: Józefka Quarry south of Górnó, Holy Cross Mountains.

TYPE HORIZON: Szydłówek Beds, Givetian-Frasnian boundary beds.

ETYMOLOGY: *jozefkae* – after Józefka, the name of



Text-fig. 14. Transverse serial sections of *Desquamattia globosa jozefkae* Baliński subsp. nov. through two shells ZPAL Bp 81/18 (A) and ZPAL Bp 81/19 (B) from Józefka Quarry. Numbers refer to distances in mm from ventral umbo

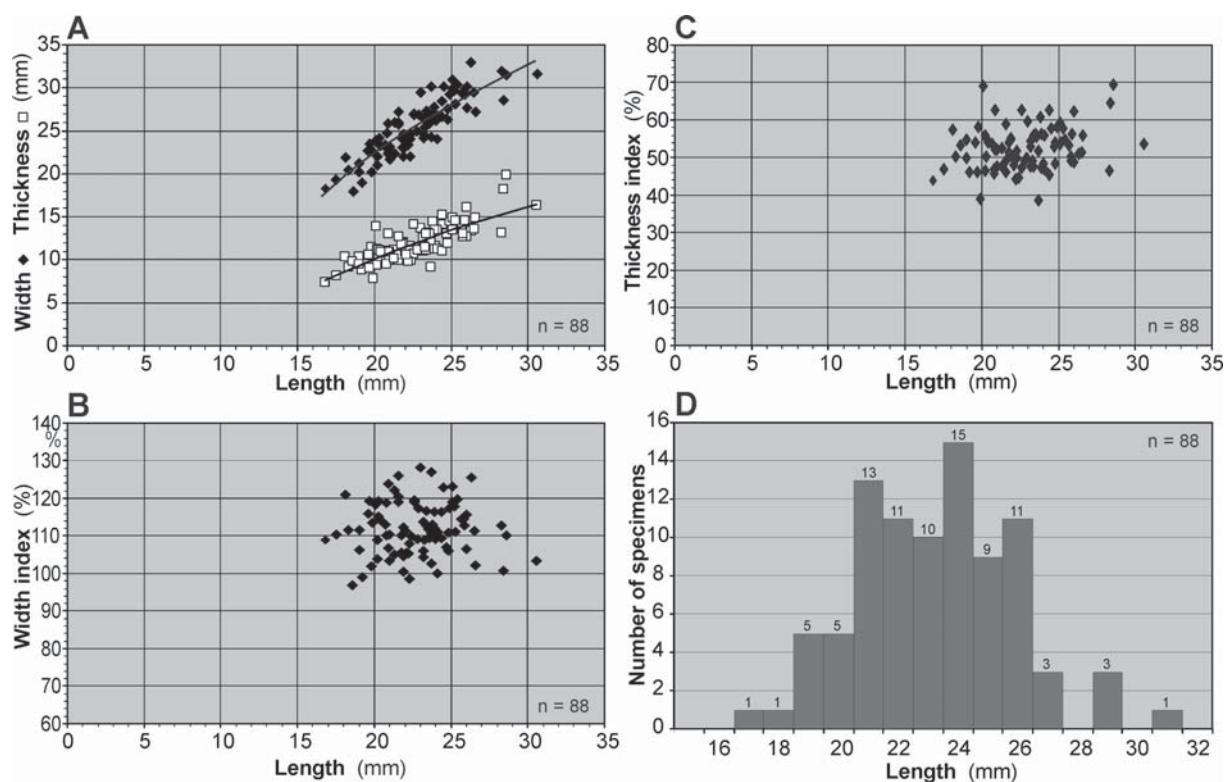
the hill with the quarry, in which the studied material was found.

DIAGNOSIS: Medium-sized, rounded to transversally elliptical in outline, uniplicate; cardinal margin attains 44–62% of shell width, anterior margin usually truncated, rarely weakly arched or weakly indented; ventral interarea distinct, apsacline to orthocline; dorsal fold absent or very low; 11–13 ribs per 10 mm at distance of 20 mm from ventral beak.

DESCRIPTION: Shell medium-sized for the subgenus, typically 21–27 mm in width, largest up to

33 mm wide, rounded to transversally elliptical in outline, slightly wider than long to subequal (Text-fig. 15); cardinal margin nearly straight, attaining 44–62% of shell width, lateral margins rounded, anterior margin usually truncated.

Ventral valve weakly convex in lateral profile, with weakly convex to weakly concave flanks; sulcus wide, appears at midlength, shallow; tongue absent to very short; interarea distinct, almost flat to slightly concave, weakly apsacline to orthocline, reaching 1.4–1.8 mm in height; deltidial plates conjunct, delicate with apical foramen surrounded by distinct foraminal rim (Text-figs 7F, 8F–G).



Text-fig. 15. Diagrams of shell dimensions in *Desquamatia globosa jozefkae* Baliński subsp. nov. from Józefka Quarry. A – scatter plot of shell width (solid diamonds) and shell thickness (white squares) to shell length. B – scatter plot of shell width index (width/length) to shell length. C – scatter plot of shell thickness index (thickness/length) to shell length. D – size-frequency distribution. n is the number of specimens measured

Dorsal valve more convex than ventral valve, regularly arched in lateral profile, with slightly swollen umbonal and median regions; fold absent or very low, poorly distinguishable near anterior margin of adult forms.

Ventral valve interior with strong teeth, small accessory lobe and small dental cavities or dental nuclei. Dorsal interior with flat, subhorizontal hinge plates separated by moderately wide cardinal pit, posteriorly lined with attachment of adductor muscles; median myophragm wide, triangular in transverse section posteriorly and domed more anteriorly, with shallow median groove (Text-fig. 14).

Ornamentation of tubular, bifurcating ribs, 11–13 per 10 mm measured at distance of 20 mm from ventral beak. Growth lamellae and micro-ornament not observed due to extensively decorticated shell exteriors.

REMARKS: Racki (1993a) discussed a wide range of morphological variability of *D. globosa* (Gürich, 1896) that he revealed from several localities in the

south-western part of the Kielce Region. He proposed to regard those atrypids as representing different subspecies within *D. globosa*. Besides the nominative subspecies, he proposed *D. globosa aequiconvexa* Racki, 1993 and *D. globosa sitkovkensis* Racki, 1993. He also noted (Racki 1993a, p. 322) that discrimination of different subspecies of *D. globosa* from different localities or beds, but on a rather limited area in the south-eastern part of the Holy Cross Mountains is biologically more realistic than attributing these forms to similar species known from distant areas of the world. The present author agrees with this point of view and prefers to regard the atrypid from Józefka as a new subspecies within *D. globosa*.

The present subspecies is externally similar to *D. g. globosa* (Gürich, 1896) described by Gürich (1896) and re-described by Racki and Baliński (1981) and Racki (1993a) from the Givetian to Frasnian transitional beds in the Chęciny area, Holy Cross Mountains. Both subspecies have a high and distinct ventral interarea and attain a similar shell size and

outline. Shells of *D. g. jozefkae* Baliński subsp. nov. are more transverse and have less rounded anterior margin. Furthermore, they are generally less globose, attaining, on the average, about 53% of the shell length, whereas adults of *D. g. globosa* usually reach 60–80%. Sectioned specimens of both forms also reveal differences in the development of dental cavities. In *D. g. globosa* they are quite large and better developed than in *D. g. jozefkae* Baliński subsp. nov. (compare with Racki and Baliński 1981, fig. 16).

Desquamatia globosa aequiconvexa Racki, 1993 is distinguished from *D. g. jozefkae* Baliński subsp. nov. by a mostly equibiconvex shell, more expanded posterolateral extremities and a finer shell ribbing. *Desquamatia globosa sitkovkensis* Racki, 1993 seems to be closest to *D. g. jozefkae* Baliński subsp. nov. although it differs in a more elongated and more convex shell and having widely spaced, large frills. Although the lack of frills in *D. g. jozefkae* Baliński subsp. nov. seems to be characteristic, it may be partly, the result of taphonomic constrains.

Desquamatia globosa jozefkae Baliński subsp. nov. is easily distinguishable from the lower Givetian *Desquamatia (D.) deserti* Halamski and Baliński, 2013 of Morocco (Halamski and Baliński 2013) by its smaller, wider shell that does not narrow anteriorly and having a much coarser shell ribbing. *Desquamatia costata* Cooper and Dutro, 1982 from the Oñate Formation of New Mexico (Cooper and Dutro 1982) is generally similar to the present form, but has a wider and less angular hinge margin and more dorsi-biconvex shell. The subspecies from Józefka is similar in the general shell outline, convexity of valves and well marked ventral interareas to *Desquamatia (Synatrypa) kimberleyensis* (Coleman, 1951) described by Gray (1978, pp. 20–33, pl. 11, figs 1–3) from the Givetian–Frasnian Sadler Limestone of the Canning Basin (Australia). The former differs by having a narrower hinge margin and wider anterior margin. *Desquamatia* cf. *kimberleyensis* from the lower Frasnian of southern China (Ma *et al.* 2006) generally differs from *D. g. jozefkae* Baliński subsp. nov. by having a more elongated and more dorsibiconvex shell, lower ventral interarea and finer radial ornamentation.

CONCLUSIONS

An isolated accumulation of densely packed brachiopods, more than 3 m thick and 10 m wide, has been found in Józefka Quarry in the central part of the Holy Cross Mountains. The complex was depos-

ited most probably as an allochthonous bed within the Middle/Upper Devonian Szydłówek Beds. The low-diversity assemblage is dominated by the atrypide *Desquamatia globosa jozefkae* Baliński subsp. nov. and, to a lesser degree, by the rhynchonellide *Coeloterorhynchus dillanus*. Less frequent are specimens representing the genera: *Hypothyridina*, *Schizophoria* and *Phlogoiderynchus*. Analysis of the internal morphology of the dominating forms allows us to conclude that the assemblage represents forms which might have been well adapted to deeper water settings characterized by lower nutrient concentrations.

Conodonts found within the coquina bed indicate that the stratigraphic position of the shell accumulation is close to the Givetian/Frasnian boundary. This confirms an earlier statement that the lower boundary of the Szydłówek Beds is diachronous.

The brachiopods are associated with numerous crinoids and less frequent bryozoans, receptaculitids (Palaeozoic problematica), sponges and solitary corals. Several sedimentary features of this unit support the conclusion that it formed by redeposition to a deeper part of the intrashelf basin, characterizing the sedimentation of the Szydłówek Beds. However, the high degree of brachiopod shell articulation and the only partial infilling of shells, indicate a rather short distance of redeposition. The brachiopods mixed with crinoidal debris were transported by low velocity, high-density gravity-induced debris flows.

The comparison of the spectrum of bioclasts from higher parts of the investigated section indicates that the source area for the coquina material was not located in the shallow parts of the central platform (“Dyminy Reef”), but most probably it was transported from the submarine sea-mount to the north of present-day Józefka. A characteristic spectrum of biota within the coquina bed, devoid of forms typical of the Middle Devonian shallow-water faunal associations, allows us to conclude that the triggering mechanism of allochthonous deposition was rather an earthquake than storm activity.

The enormous thickness of the brachiopod complex is probably caused by the sinking of bioclastic material in a soft, muddy bottom, similarly to other limestone units, composed of basal marls, intercalated with allochthonous bioclastic layers.

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