

Molluscs from the Early Frasnian Goniatic Level at Kostomłoty in the Holy Cross Mountains, Poland

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The unique goniatic-rich pyritic level, 1.6 m thick, exposed at Kostomłoty (Holy Cross Mountains, central Poland) represents a distinct, local biotic event in the Early Frasnian interval corresponding to the inception of a major geochemical (carbon cycling) perturbation in the stagnant deep-water and oxygen-deficient Kostomłoty basin. The taxonomic and palaeoecologic characteristics of molluscan fossil associations from the Goniatic Level are presented. Most of the goniaticids and orthoconic nautiloids from the studied fossil assemblages are juvenile conchs or protoconchs, or incomplete phragmocones and represent the genera *Acanthoclymenia* and *Linguatormoceras*, the former being predominant, and a single adult specimen probably of the genus *Koenenites*. In contrast, gastropods and bivalves are generally well preserved and identifiable to species level. Two new species are described: a gastropod *Palaeozygopleura (Bohemozyga) pyritica* sp. nov. and a bivalve *Glyptohallicardia multicostata* sp. nov. These studied molluscs and also amphiporoids are allochthonous elements which must have been transported into the deeper settings during sea-level rise and flooding of fringing reefs (Timan Event) and/or storm events, and there were mixed with pelagic cephalopods. Probably, a sea-level rise even led to flooding of nearby areas, and thus to introduction of pelagic material (juvenile cephalopods) into reefal settings, and then back to the deeper water again by the quasi-estuarine circulation of water masses.

Key words: Goniaticida, Nautiloidea, Gastropoda, Bivalvia, palaeoecology, Frasnian, Devonian, Poland.

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Introduction

The present paper is a continuation of a study by Racki et al. (2004), who presented a general characteristic of the unique Late Devonian facies at Kostomłoty (Holy Cross Mountains, central Poland; Fig. 1), which consists of organic-rich marly shales and a distinctive pyritic fossiliferous horizon, 1.6 m thick, called the Goniatic Level after Racki et al. (1985). The rich Early Frasnian faunal assemblage, associated with these diminutive goniaticids, consists of orthoconic nautiloids, tentaculitids (*Styliolina*), conodonts, bivalves, and gastropods, all with pyritised shells. Collections also include brachiopods and amphiporoids, which represent a non-pyritised fauna. Racki et al. (2004) documented the geochemical and depositional signatures of the Goniatic Level in detail, combined with general palaeontological-ecological description and analyses, derived from previous unpublished Master's theses (Więzik 1984; Niemczyk 2003).

This study includes an environmental reconstruction of the Goniatic Level, as well as present some notes on previous identifications of goniaticids, and gives a first taxonomic overview of bivalves and gastropods.

A coeval Frasnian goniatic-bearing facies is known only from a single locality in the northerly Łysogóry basin, at

Ściegna (or Ścignia = Wzdół Plebański in Kościelniakowska 1967) near Bodzentyn (see Dzik 2002; Racki et al. 2004: 277); Penczek (1995) presented new data on the poorly-known fossil assemblage from there. The present paper is a part of the integrative event-stratigraphical study across the Early–Middle Frasnian boundary beds (Racki et al. 2004; Pisarzowska et al. 2006), corresponding to the *Palmatolepis transitans*–*Palmatolepis punctata* zonal boundary (as formally recommended by the Subcommittee on Devonian Stratigraphy; Ziegler and Sandberg 2001).

Institutional abbreviation.—GIUS, Department of Paleontology and Biostratigraphy of the University of Silesia, Sosnowiec, Poland.

Stratigraphic setting

In the Devonian time the area of the Holy Cross Mountains was divided into two distinct palaeogeographic-tectonic regions: the Łysogóry palaeolow and the Kielce palaeohigh (Szulczewski 1971, 1995; Racki 1993). The Frasnian Dyminy Reef was surrounded by two intrashelf basins: Chęciny-Zbrza subregion in the south and Łysogóry-Kosto-

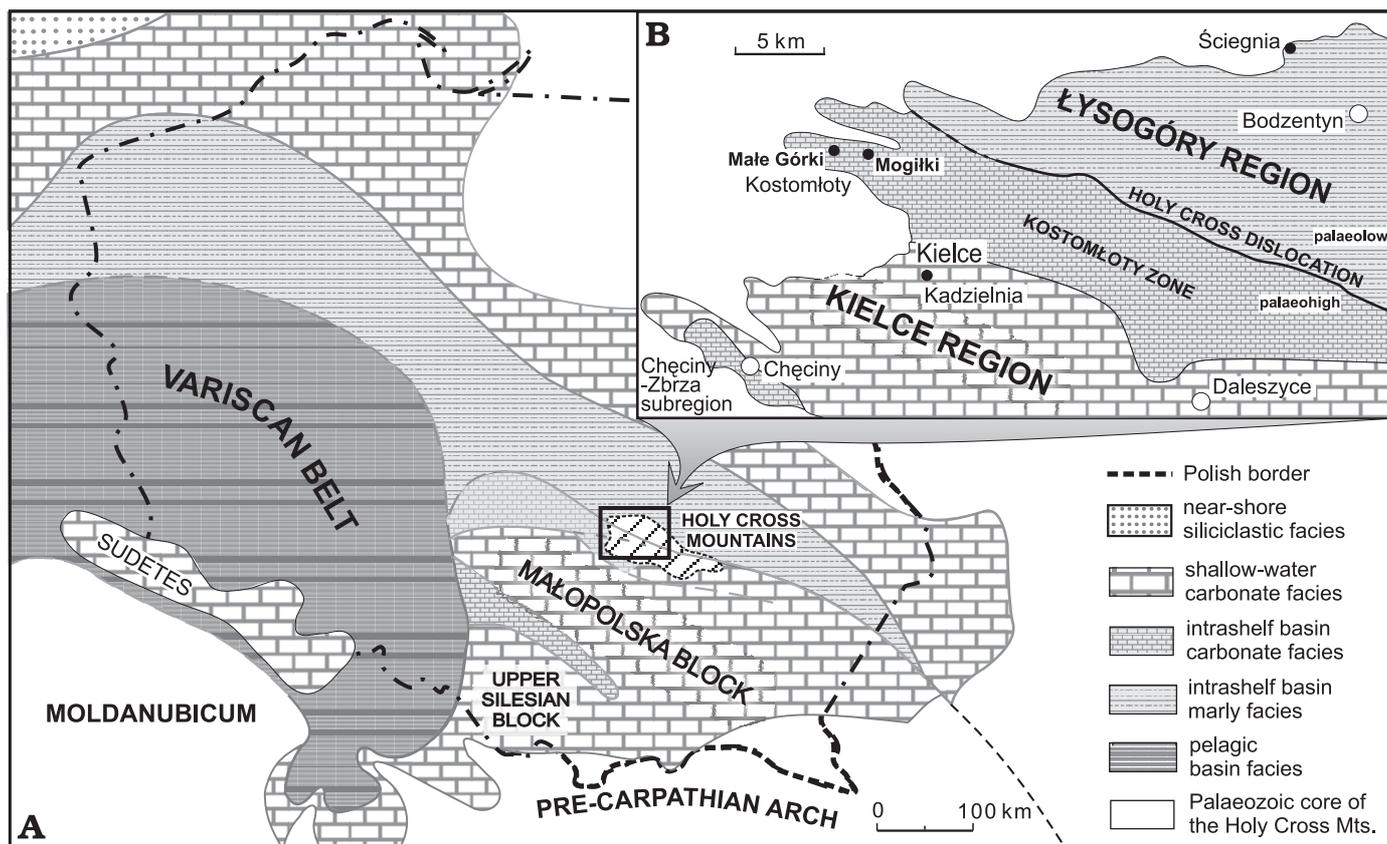


Fig. 1. A. Location of Holy Cross Mountains against the palaeogeographic framework of the Devonian in Poland (modified after Racki 1993: fig. 1). B. Givetian–Frasnian palaeogeography of the Holy Cross Mountains (based on Racki 1993: fig. 2), with location of the Kostomłoty and Ściegnia sites.

młoty subregion in the north (Racki 1993). The Kostomłoty transitional zone continued further to the north into the deeper Łysogóry basin, situated between the Małopolska Block and the East European Platform (see Szulczewski 1995).

During field works in 1996–1997 and 2003, new specimens of molluscs were collected by two of authors (WK and MR) of present paper, in the western corner of the Kostomłoty II quarry (Małe Górki; section Kt-IIW in Racki et al. 2004: fig. 2). Lithological logs and a detailed discussion of the goniatite-rich deposits have been presented in previous papers (Racki 1985; Racki et al. 1985, 2004; Racki and Bultynck 1993). This fossiliferous level, dated by conodonts as upper *Palmatolepis transitans* Zone (Racki and Bultynck 1993), and *Ancyrodella africana*–*Ancyrodella pramosica* level (Pisarczyńska et al. 2006), is situated within the uppermost part of the Szydłówek Beds, and is represented by a series of partly strongly tectonically disturbed, black, marly shales and thin-bedded, homogeneous, micritic limestone. Notably, this distinctive horizon documents a conspicuous biotic response to the inception of a major geochemical perturbation in carbon cycling, and global hypoxic-transgressive Timan Events (Becker and House 1997; House 2002), in the stagnant, deep-water, and oxygen-deficient Kostomłoty basin (Racki et al. 2004; Pisarczyńska et al. 2006).

This pyrite-rich fossiliferous horizon is essentially absent in the nearby disused Mogilki quarry (= Kostomłoty V, Kt-V; Racki et al. 2004; Pisarczyńska et al. 2006), ca. 2 km to the east. In that section, centimetre-sized pyrite crusts and shaly partings occur just below the boundary between the Szydłówek and Kostomłoty beds but there are no pyritised fossils.

A similar pyrite-rich fossiliferous horizon occurs, however, in the Ściegnia section (Łysogóry area), some 8 km northwest of the town of Bodzentyn, and 30 km east from Kostomłoty (Fig. 1). Within the set B₂, consisting of grey-olive marls and dark brown marly shales and limestone, with few detrital (mainly crinoidal) intercalations, there are two shaly levels with pyritised Early Frasnian fossils within a 1.5 m interval (*A. africana*–*A. pramosica* conodont level; Racki in Penczek 1995).

Material and methods

The collection studied consists of about 3000 specimens, below 10 mm in size and with an average size of 3–4 mm. Most of the material is strongly pyritised; a few goniatitids were prepared mechanically, using standard methods, but the ma-

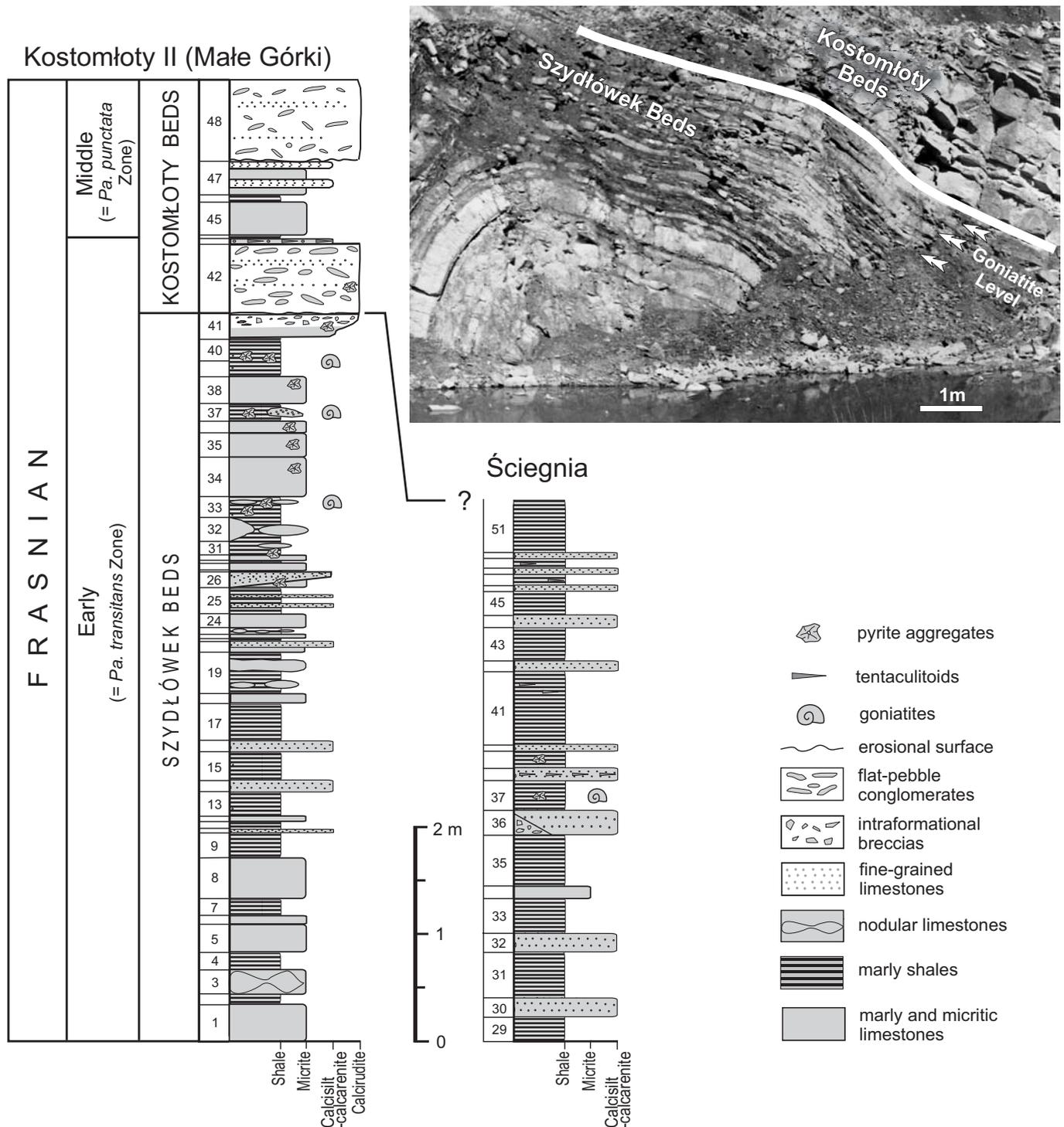


Fig. 2. Middle portion of the section exposed in the westerly corner at the Kostomłoty II quarry (Małe Górki), documenting the boundary between the Szydłówek and Kostomłoty Beds (Early–Middle Frasnian), and with the Goniatite Level marked (after Racki et al. 2004), as well as the upper part of Ściegna section (after Racki in Penczek 1995). Abbreviation: *Pa.*, *Palmatolepis*.

jority of the specimens were extracted from the rock samples in the laboratory. First, the material was crushed, then dissolved in 20% acetic acid and left for a few days. Unfortunately, this method was not very successful as a large portion of marly matrix was left. Secondly, samples were crushed, then boiled in a 5% solution of glauber salt and cooled down.

Following that, the fossiliferous residue was divided into fractions using sieve mesh widths of 0.1 and 0.3 mm and then manually picked up. Images of fossils have been prepared using a Scanning Microscope, Philips XL30 ESEM/TMP (environmental chamber—without coating). Some larger specimens have been coated with NH₄Cl.

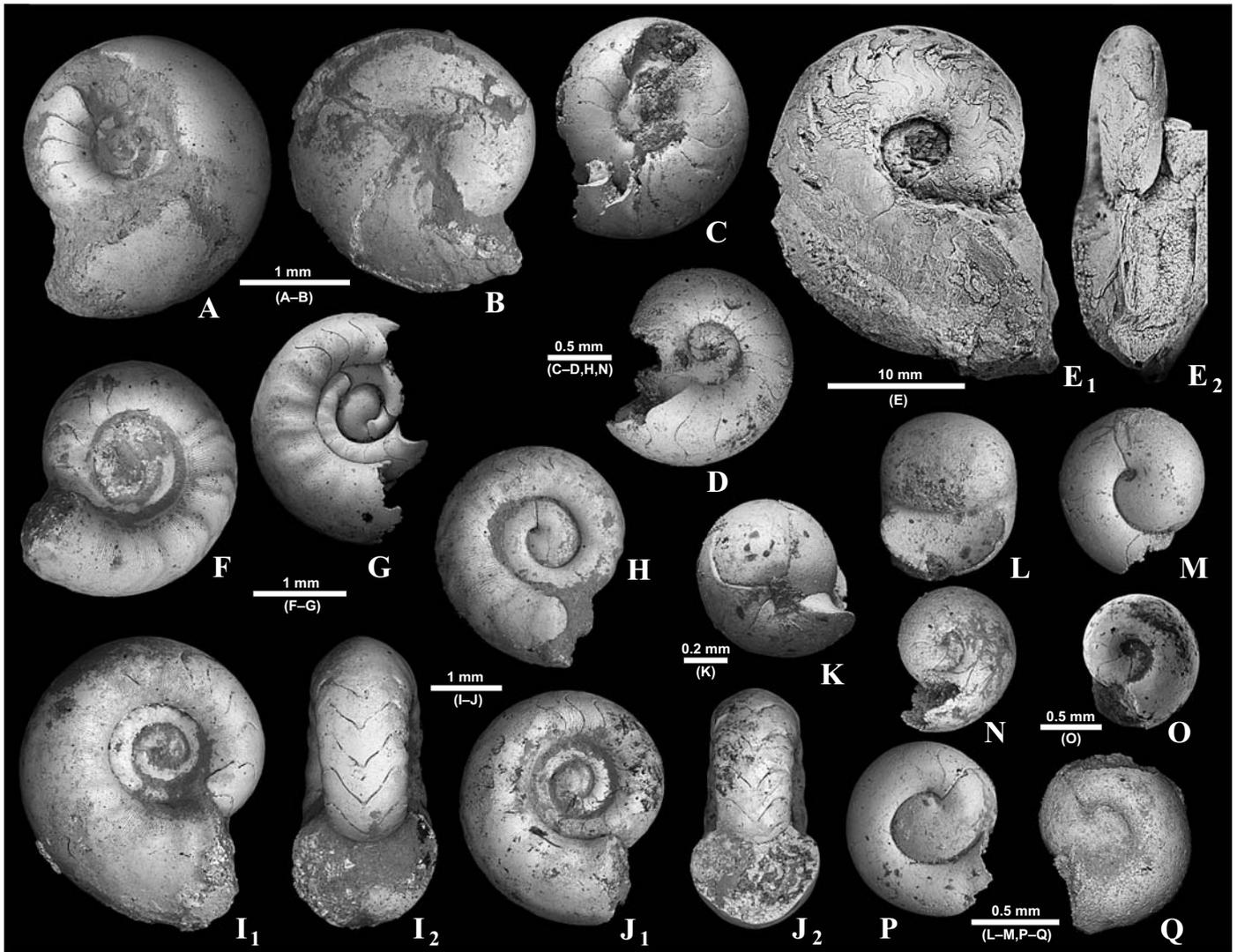


Fig. 3. Early Frasnian goniatites from the Goniatite Level at Kostomłoty II quarry (Małe Górki) and Ściegna, Holy Cross Mountains, Poland. A–D. Juvenile forms of *Linguatormoceras* sp., GIUS 4-2304 Kos-34/2 (A), GIUS 4-2304 Kos-34/1 (B), GIUS 4-2833 Kos-51/2 (C), and GIUS 4-2833 Kos-51/1 (D) in lateral views. E. Adult form of *Koenenites* sp., GIUS 4-2837 Kos-55 in lateral (E₁) and apertural (E₂) views. F–J. Juvenile forms of *Acanthoclymenia* sp. F. GIUS 4-2834 Kos-52/1 in lateral view. G. GIUS 4-2834 Kos-52/2 in lateral view. H. GIUS 4-2836 Kos-54 in lateral view. I. GIUS 4-2298 Kos-28/1 in lateral (I₁) and apertural (I₂) views. J. GIUS 4-2298 Kos-28/2 in lateral (J₁) and apertural (J₂) views. K–Q. Indeterminate goniatite protoconchs, GIUS 4-2835 Kos-53/1 (K), GIUS 4-2835 Kos-53/2 (L), GIUS 4-2835 Kos-53/3 (M), GIUS 4-2835 Kos-53/4 (N), GIUS 4-2835 Kos-53/5 (O), GIUS 4-2835 Kos-53/6 (P), and GIUS 4-2847 Wz-41a/2 (Q) in lateral views.

Molluscan associations from Goniatite Level

The taxonomic composition of the molluscan assemblage from the Goniatite Level at Kostomłoty (Małe Górki) shows a predominance of juvenile shells of goniatitites followed by orthoconic cephalopods; bivalves and gastropods are less numerous (Niemczyk 2003). In contrast, the number of bac-tritids, goniatitids and bivalves at Ściegna is distinctly lower and styliolinids predominate (Penczek 1995). Common styliolinids include widespread *Styliolina* ex gr. *nucleata* Karpinsky, 1884 and *S. domanicensis* Lyashenko, 1959 at Kostomłoty (Hajłasz 1993).

Cephalopods.—These are represented mostly by internal moulds of goniatites; associated are nautiloids (?) and bac-tritids. The goniatites in particular are small and represented mostly by fragments of phragmocones, rare adult forms, juvenile individuals or even protoconchs (Fig. 3), which suggests their autochthonous nature. All nautiloid remains are also juvenile orthoconic shells, while bac-tritids comprise a few protoconchs and parts of phragmocones, and juvenile specimens (Fig. 4).

This state of preservation explains why identification of cephalopods is problematic; previous authors have made various attempts. The ammonoid fauna, discovered by Jan Malec, was first studied by Dzik (in Racki et al. 1985), who recorded the genera *Manticoceras*, *Epitornoceras*, *Probelo-*

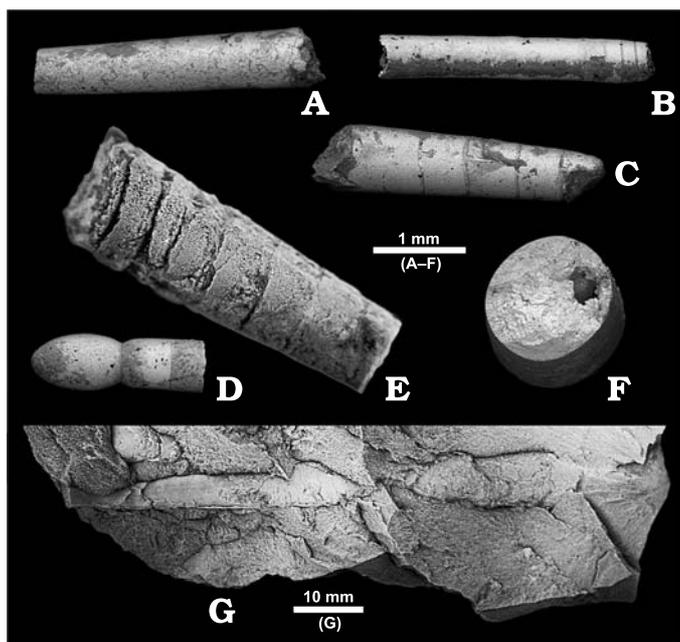


Fig. 4. Indeterminate parts of phragmocones and juvenile forms of nautiloids and bactritids from the Goniatic Level, uppermost Szydłówek Beds (Early Frasnian) at Kostomłoty, Holy Cross Mountains, Poland. A–C. Fragments of bactritid shells, GIUS 4-2832 Kos-50/1 (A), GIUS 4-2832 Kos-50/2 (B), and GIUS 4-2832 Kos-50/3 (C). D. Bactritid protoconch, GIUS 4-2832 Kos-50/4. E. Fragment of nautiloid phragmocone, GIUS 4-2306 Kos-36/1. F. Cross-section of bactritid shell, GIUS 4-2832 Kos-50/5. G. Nautiloid shell, GIUS 4-2580 Kos-47.

ceras, and *Tornoceras*. Later, Dzik (2002) revised previous assignments of goniatic material from Kostomłoty, and re-identified it as *Koenenites lamellosus* and *Acanthoclymenia genudewa*. Niemczyk (2003) identified only *Acanthoclymenia* and *Linguatormoceras* while Racki et al. (2004), following comments made by Thomas Becker (personal communication, 2004), pointed out that a juvenile *Manticoceras* was certainly present in the material; in particular, some specimens linked with the genus *Koenenites* by Dzik (2002) probably belong to the *Manticoceras lamed* group.

The present authors decided to identify goniatics to only the generic level because of insufficient preservation and predominance of juvenile forms and protoconchs (Fig. 3), which are impossible to identify at the species level. In total, the material studied (about 500 specimens) represents only genera *Acanthoclymenia* and *Linguatormoceras*, the former being predominant and a single phragmocone of probably *Koenenites* genus (Fig. 3E). Incidentally, the cephalopod association at Ściegna includes nautiloids and goniaticids, mainly juvenile shells of *Acanthoclymenia* sp. (see Fig. 3Q).

Gastropods.—In comparison to cephalopods, gastropods (Fig. 5) are represented mostly by large-sized composite moulds with well-preserved external ornament. These are exclusively adult forms. Contrary to the cephalopods, generic and specific identifications have proved far less problematic, and four taxa have been reliably identified: *Lahno-*

spira taeniata (Sandberger, 1842), *Palaeozygopleura (Bohemozyga) pyritica* sp. nov., *Naticopsis* aff. *N. kayseri* (Holzapfel, 1895), and indeterminate subulitids. *L. taeniata* is dominant in this association (Niemczyk 2003).

These species are usually characteristic of reefal environments (see Krawczyński 2002, 2006); for this reason, the gastropod association is allochthonous. It was probably transported from the adjacent Dyminy Reef complex, developed on the periphery of the southerly Kielce carbonate platform (see Fig. 1B), as were some representatives of Amphiporoidea (Racki et al. 2004).

Bivalves.—Bivalves (Fig. 6) are also represented by pyritised internal moulds, mostly praecardioids, such as *Glyptohallicardia* cf. *palmata* (Goldfuss, 1837), *G. ferruginea* (Holzapfel, 1895), *G. aff. G. conversa* (Clarke, 1904), *G. multicostata* sp. nov. and ?*Cabricardia* sp., accompanied by a few pteroids such as ?*Metrocardia* sp. and *Leptodesma* sp. *G. multicostata* sp. nov. predominates in the bivalve assemblage from the Kostomłoty (Mały Górki) section (see Niemczyk 2003), and is the single bivalve species known at Ściegna (see Fig. 6F).

In general, most of the bivalves from the Goniatic Level are infaunal or semi-infaunal forms (Grimm 1998). They are juveniles and adults of mostly small-sized taxa. Probably the bivalve association is *in situ* or might have been transported over short distances.

Palaeoenvironmental interpretation

Our environmental reconstruction (Fig. 7) is based on a general analysis of ecological characteristics of the Frasnian assemblages as well as on geochemical data presented in Racki et al. (2004). The latter document a benthic oxygen deficiency, and the presence of framboid pyrite implies dysoxic conditions; very intensive early skeletal pyritisation also supports a dysaerobic facies assignment.

The Kostomłoty-Mały Górki and Ściegna sections differ in the taxonomic composition of assemblages from the pyrite-rich horizons studied. Because of shallower-water proximal conditions, the Mały Górki fauna is represented by diverse benthic (bivalves and gastropods, brachiopods), nektonic (nautiloids and goniaticids) as well as planktonic (styliolinids) forms. In comparison, the deeper deposits at Ściegna yield fewer representatives of benthic (bivalves) and nektonic (nautilids and goniaticids) forms, and the assemblage is dominated by styliolinids. Surprisingly, the nearby Mogiłki section has not yielded fauna from the pyrite-rich level.

The goniatic- and styliolinid-rich assemblage studied mark the Timan Event as episodic with localized blooms in suitable, nutrient-rich conditions and possibly increased primary production (see Racki et al. 2004; Piszczowska et al. 2006). The mixed assemblage consists of predominantly pelagic biota (goniaticids, bactritids, nautiloids, and tentaculitids), but also of evidently allochthonous elements, such as

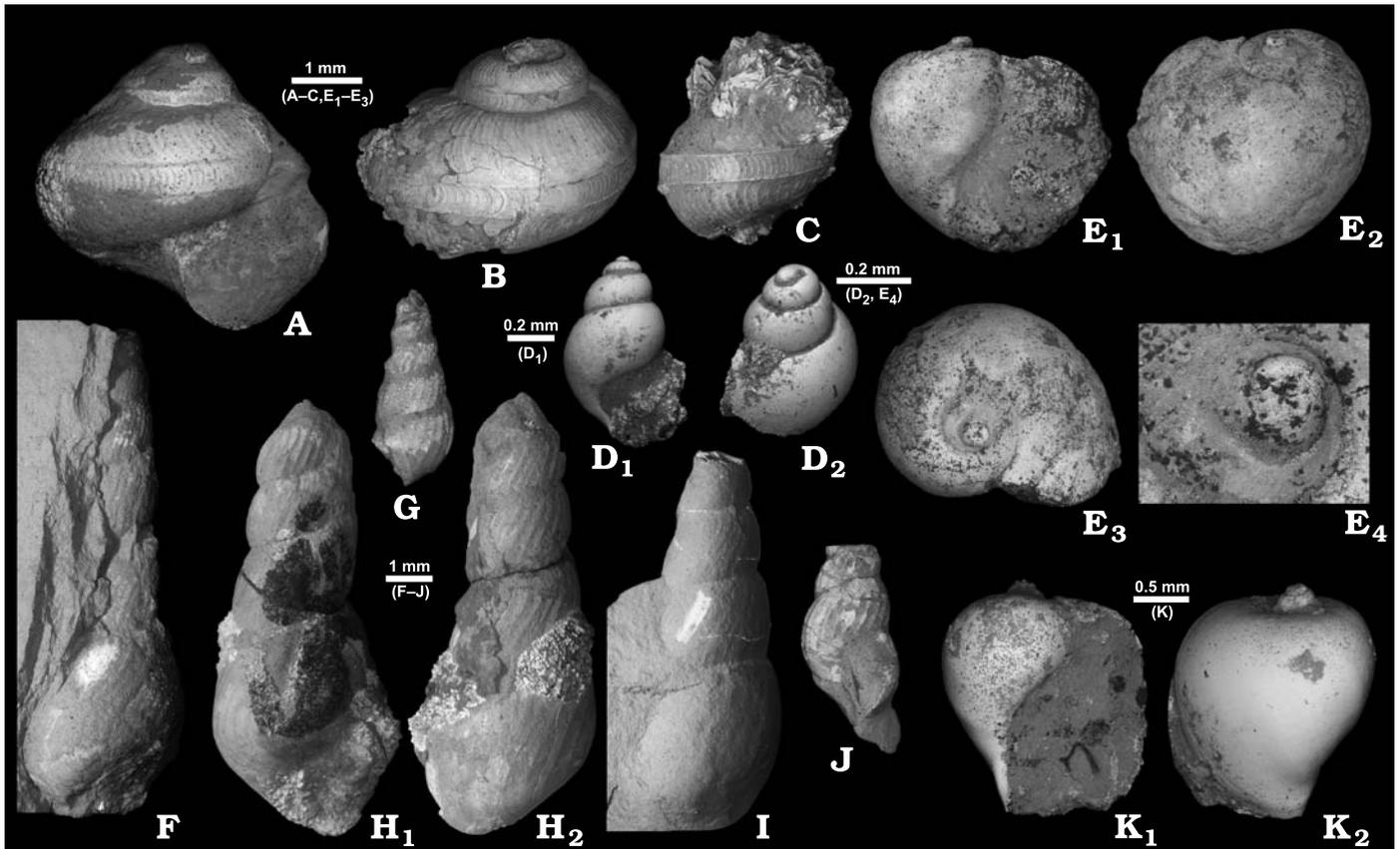


Fig. 5. Gastropods from the Early Frasnian Goniatic Level (uppermost Szydłówek Beds) at Kostomłoty, Holy Cross Mountains, Poland. **A–C.** *Lahnospira taeniata* (Sandberger, 1842). **A.** GIUS 4-2282 Kos-12 in apertural view. **B, C.** GIUS 4-2276 Kos-6 (**B**) and GIUS 4-2277 Kos-7 (**C**) in lateral views. **D.** Subulitidae indet., GIUS 4-2289 Kos-19, in apertural (**D**₁) and lateral (**D**₂) views, with protoconch visible. **E, K.** *Naticopsis* aff. *N. kayseri* Holzapfel, 1895. **E.** GIUS 4-1164 Kos-2 in pertural (**E**₁), lateral (**E**₂), and apical (**E**₃) views and cycloneritid-type protoconch (**E**₄). **K.** GIUS 4-2288 Kos-18 in apertural (**K**₁) and lateral (**K**₂) views. **F–J.** *Palaeozygopleura (Bohemozyga) pyritica* sp. nov. **H.** GIUS 4-2284 Kos-14 in apertural (**H**₁) and lateral (**H**₂) views of holotype. **F, G, I.** GIUS 4-2287 Kos-17 (**F**), GIUS 4-2285 Kos-15/1 (**G**), and GIUS 4-2286 Kos-16 (**I**), lateral views with opisthoconical ornamentation visible. **J.** GIUS 4-2285 Kos-15/1, apertural view of shell fragment.

amphiporoids and gastropods, which suggests some possible scenario for the appearing of this unique level.

Apparently, the basinal facies represented in the studied section comprised two different, probably adjacent, environmental settings: one of them well-oxygenated, supporting a thriving population of infaunal bivalves, gastropods, and possibly also cephalopod spatfall (hence protoconchs and juvenile shells), the other dysoxic or episodically anoxic, as envisaged by laminated sediment, a general lack of bioturbation and a low diversity of presumed benthos, mostly brachiopods (supplemented by geochemical signals, and sedimentary interpretations of Racki et al. 2004). During an Early Frasnian eustatic sea-level rise (Subcycle IIB/C of Racki 1993), i.e., flooding of nearby fringing reefs during the Timan Event of Becker and House (1997), and/or storm episode(s), these faunal elements were mixed by the sudden introduction of those thriving near-reefal communities into a deeper-water, less oxygenated setting (see also Racki and Bultynck 1993). This Early Frasnian timespan was marked by a maximum extension northward of the initial Dyminy Reef into the Kostomłoty intrashelf basin (Racki and Sobstel

2004), but the Timan Event corresponded to overall but transient carbonate crisis that led to expanding growth of the Kadzielnia-type mud mounds in the ramp setting (see discussion in Piszczowska et al. 2006).

The open-marine basin under study, with oxygen-poor denitrified waters, but with increased chemical availability of nutrients (Racki et al. 2004), was situated comparatively closely to a reefal lagoon colonised by amphiporoid meadows (Racki 1988, 1993), and supported plankton and nekton such as styliolinids, cephalopods as well as infaunal benthos, such as bivalves (Fig. 7). During the sea-level highstand, an inflow of oxygen-poor waters into the reef lagoon area would have led to the mixing of basin and lagoonal water masses of distinctive chemical character (e.g., Racki 1993: 108). According to Kaźmierczak and Kremer (2005), the Late Devonian carbonate platform was located in an area of changing tropical climatic conditions. Allochthonous material probably also could appear here due to storms during wet (monsoonal) seasons. Hypothetically, the possible direction of water movement corresponds to quasi-estuarine circulation conditions, in which runoff and rainfall exceed evaporation (see

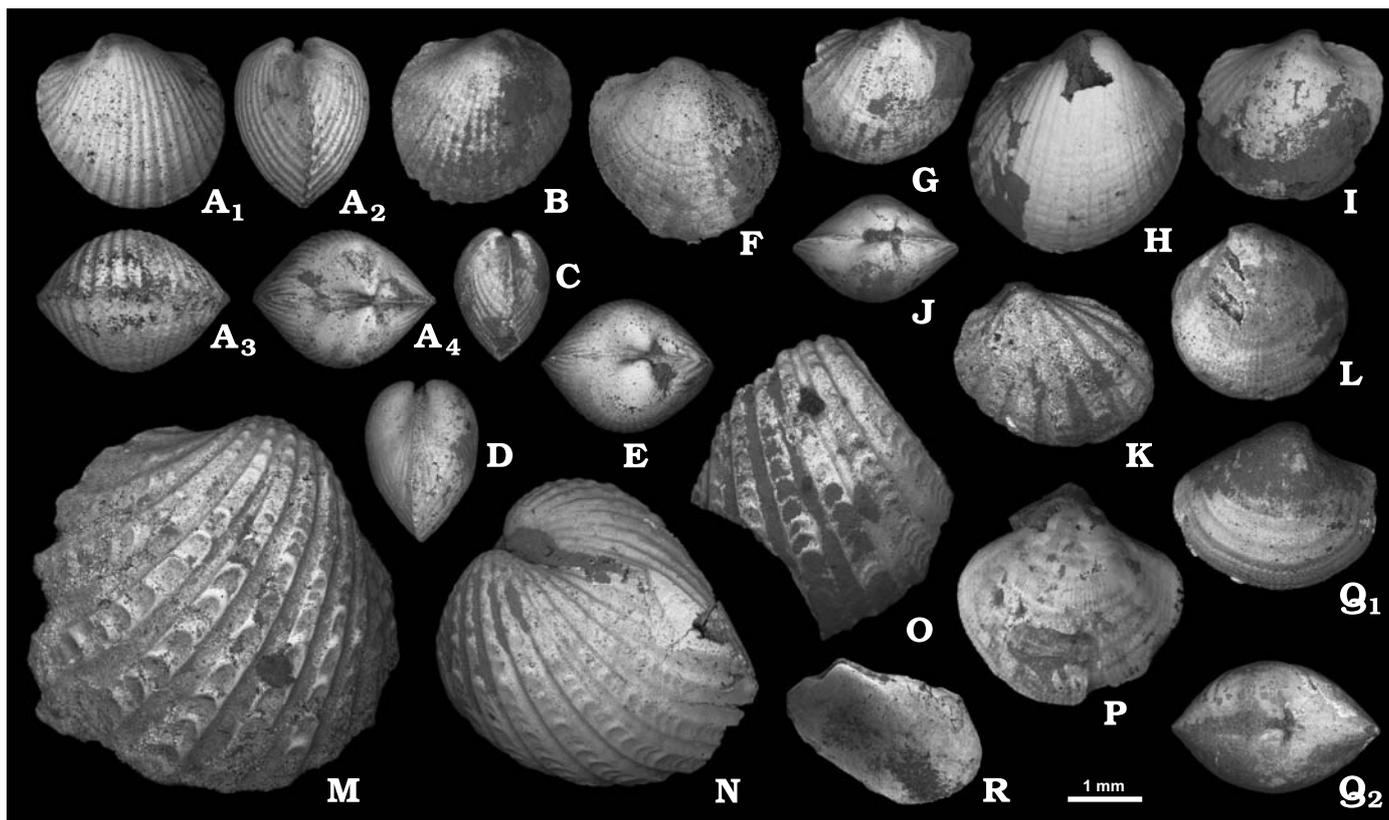


Fig. 6. Bivalves from the Early Frasnian Goniatic Level (uppermost Szydłówek Beds) at Kostomłoty and Ściegśnia, Holy Cross Mountains, Poland. A–F. *Glyptohallicardia multicostata* sp. nov. A. Holotype, GIUS 4-2290 Kos-20, in lateral (A₁), posterior (A₂), ventral (A₃), and dorsal (A₄) views. B, F. GIUS 4-2291 Kos-21/2 (B) and GIUS 4-2847 Wz-41 a/1 (F) in lateral views. C, D. GIUS 4-2291 Kos-21/1 (C) and GIUS 4-2291 Kos-21/8 (D) in posterior views. E. GIUS 4-2291 Kos-21/6 in dorsal view. G–J. *Glyptohallicardia* aff. *G. conversa* (Clarke, 1904). G–I. GIUS 4-2577 Kos-44/2 (G), GIUS 4-2577 Kos-44/1 (H), and GIUS 4-2577 Kos-44/4 (I) in lateral views. J. GIUS 4-2577 Kos-44/3 in dorsal view. K. *Glyptohallicardia* cf. *palmata* (Goldfuss, 1837), GIUS 4-2296 Kos-26 in lateral view. L. ?*Metrocardia* sp., GIUS 4-2295 Kos-25 in lateral view. M–O. *Glyptohallicardia ferruginea* (Holzapfel, 1895). M. GIUS 4-2293 Kos-23/1 in lateral view. N. GIUS 4-2293 Kos-23/2 in posterior view. O. GIUS 4-2293 Kos-23/3, fragment of valve with ornamentation visible. P, Q. ?*Cabricardium* sp. P. GIUS 4-2581 Kos-48/1 in lateral view. Q. GIUS 4-2581 Kos-48/2 in lateral (Q₁) and dorsal (Q₂) views. R. *Leptodesma* sp., GIUS 4-2297 Kos-27 in lateral view.

summary in Edinger et al. 2002: fig. 7). Nutrient and organic matter influx from land and from estuarine upwelling contributed to bioproductivity rises and organic-rich facies (total organic carbon up to 1.8%; Racki et al. 2004) during transgressions and sea-level highstands. Probably, high runoff contributed to slightly reduced salinity in the Łysogóry-Kostomłoty basin, including possible density stratification during the Early Frasnian deepening pulse. These factors could also explain an initial $\delta^{13}\text{C}$ rise as a first step of large-scale Middle Frasnian biogeochemical perturbation in this shelf domain (isotopic event I in Racki et al. 2004 and Piszarska et al. 2006), even if the isotopic record is largely diagenetically obscured in the clay-rich goniatic interval at Kostomłoty due to relatively more ^{13}C -depleted carbonate incoming from the sulphate-reduction zone (Racki et al. 2004).

In general, such kind of environmental reconstruction of the Frasnian Goniatic Level is also similar to the one presented by Nützel and Mapes (2001), based on gastropod material from Carboniferous black shales of Arkansas (USA).

However, our material does not include any larval shells of gastropods in comparison to American material.

Another resembled model of the quasi-estuarine water circulation was described by Witzke (1987) base on Upper Devonian Lime Creek–Sweetland Creek formations of the North America craton. The main circulation factor of that model is the salinity change of surface and near-surface waters. Meanwhile, Wendte and Uyena (2005) on their study of the Middle to Upper Devonian Beaverhill Lake strata from Alberta (Canada) suppose that the wind was the main factor generating the near-surface water outflow and periodic storms.

Systematic palaeontology

(W. Krawczyński)

Phylum Mollusca Linnaeus, 1758

Class Gastropoda Cuvier, 1797

Order Vetigastropoda Salvini-Plawen, 1980

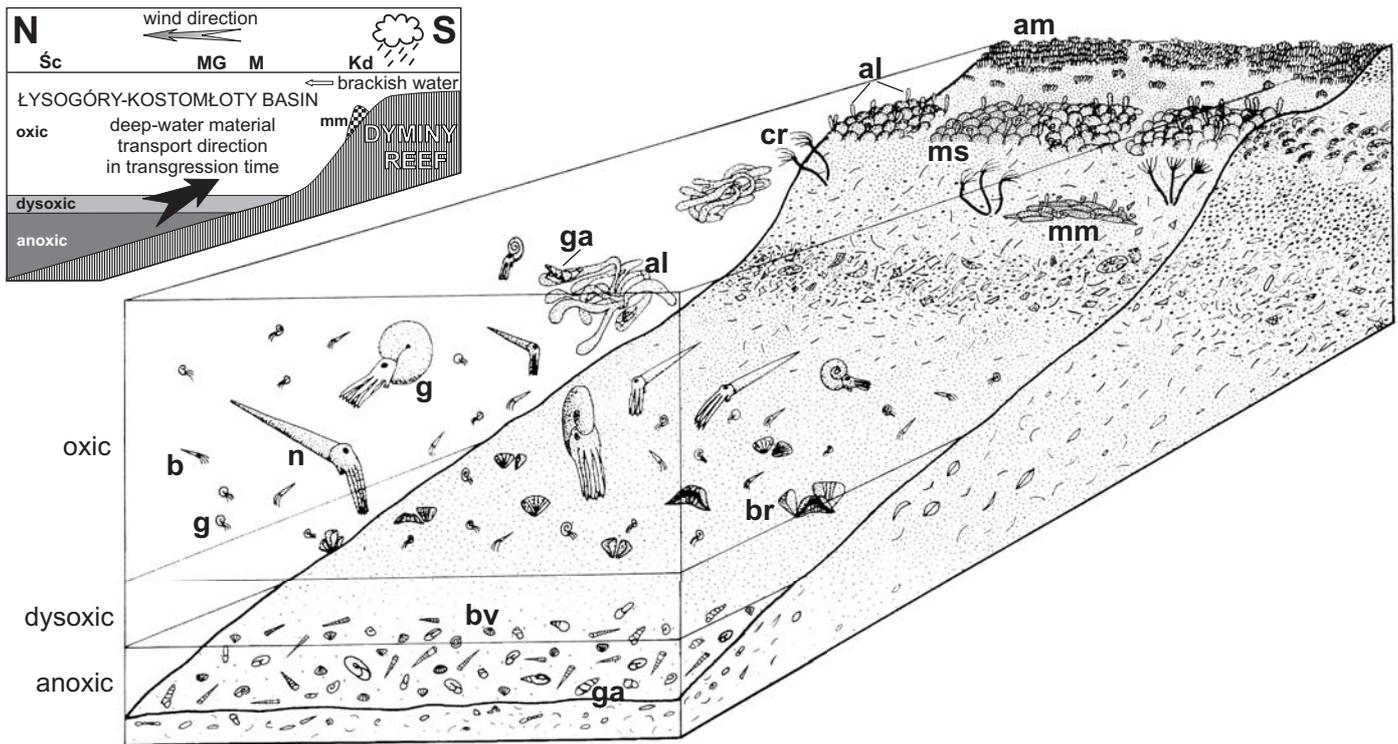


Fig. 7. Environmental reconstruction of Early Frasnian Kostomłoty intrashelf basin (see Fig. 1) during deposition of Goniatite Level. Abbreviations: al., algae; am, amphiporoids; b, bactritids; br, brachiopods; bv, bivalves; cr, crinoids; g, goniatitids; ga, gastropods; ms, massive stromatoporoids; n, nautiloids; mm, mud mounds; with probably quasi-estuarine model of water circulation (see Edinger et al. 2002: fig. 1), Kd, Kadzielnia; M, Kostomłoty-Mogilki; MG, Kostomłoty-Małe Górki; Śc, Ściegna (wind direction after Golonka et al. 1994).

Family Eotomariidae Wenz, 1938

***Lahnospira taeniata* (Sandberger, 1842)** (Fig. 5A–C).—Seven pyritised specimens with well-preserved external surface and about 170 internal moulds with the position of selenizone visible have been collected. Within the Goniatite Level at Kostomłoty, *L. taeniata* is the commonest gastropod. *L. taeniata* has been described from Givetian limestones at Villmar (Rhenish Slate Mountains; Goldfuss 1844, see also Heidelberg 2001). This species also was found in Middle Frasnian limestones of the upper Sitkówka Beds at Grabina near Kielce (Holy Cross Mountains, Poland; see Krawczyński 2002).

Order Cycloneritimorpha Bandel and Frýda, 1999

Family Neritopsidae Gray, 1847

***Naticopsis* aff. *N. kayseri* Holzapfel, 1895** (Fig. 5E, K).—Two well-preserved pyritised shells with protoconchs (a diameter of 0.3 mm; see Fig. 5E₄) have been found. The specimens studied closely resemble *N. kayseri* described by Holzapfel (1895) from Givetian limestones of Martenberg (Rhenish Slate Mountains). However, they have a lesser developed ultimate whorl, with the aperture occupying two-thirds of the shell width. These specimens are similar to the ones identified by Heidelberg and Koch (2005) as *Naticopsis* aff. *N. kayseri* Holzapfel, 1895 (see pl. 15: 12). This species belongs to the genus *Naticopsis* with some doubts because of

absent well preserved operculum. This genus has a concentric operculum, and it is main difference from the near-identical (in shell shape) Givetian genus *Hessonia* Heidelberg, 2001, which has a paucispiral one. The specimens studied originate from the Goniatite Level at Kostomłoty (uppermost Szydłówek Beds; Early Frasnian). *Naticopsis kayseri* has been recorded from the Givetian of Eisenstein and Martenberg (Holzapfel 1895), and from Schwelm (Reinisch Slate Mountains; see Heidelberg and Koch 2005).

Order Stylogastropoda Frýda and Bandel, 1997

Family Palaeozygopleuridae Horný, 1955

Genus *Palaeozygopleura* Horný, 1955

Type species: Zygopleura alinae Perner, 1907 (Perner 1907: 352, pl. 110: 5, 6), Early Devonian, Czech Republic.

Palaeozygopleura (Bohemozyga) pyritica sp. nov.

Fig. 5F–J.

Holotype: GIUS 4-2284 Kos-14 (Fig. 5H).

Type horizon: Goniatite Level in the uppermost Szydłówek Beds; *Palmatolepis transitans* conodont Zone, Early Frasnian.

Type locality: Active quarry Kostomłoty II (Małe Górki).

Derivation of the name: Alluding to the shells' preservation in pyrite.

Diagnosis.—Ornamentation consists of strong collabral ribs, which clearly differentiate this species from the similar *Palaeozygopleura (Bohemozyga) kettneri* Horný, 1955, which has more delicate, and more closely spaced, collabral

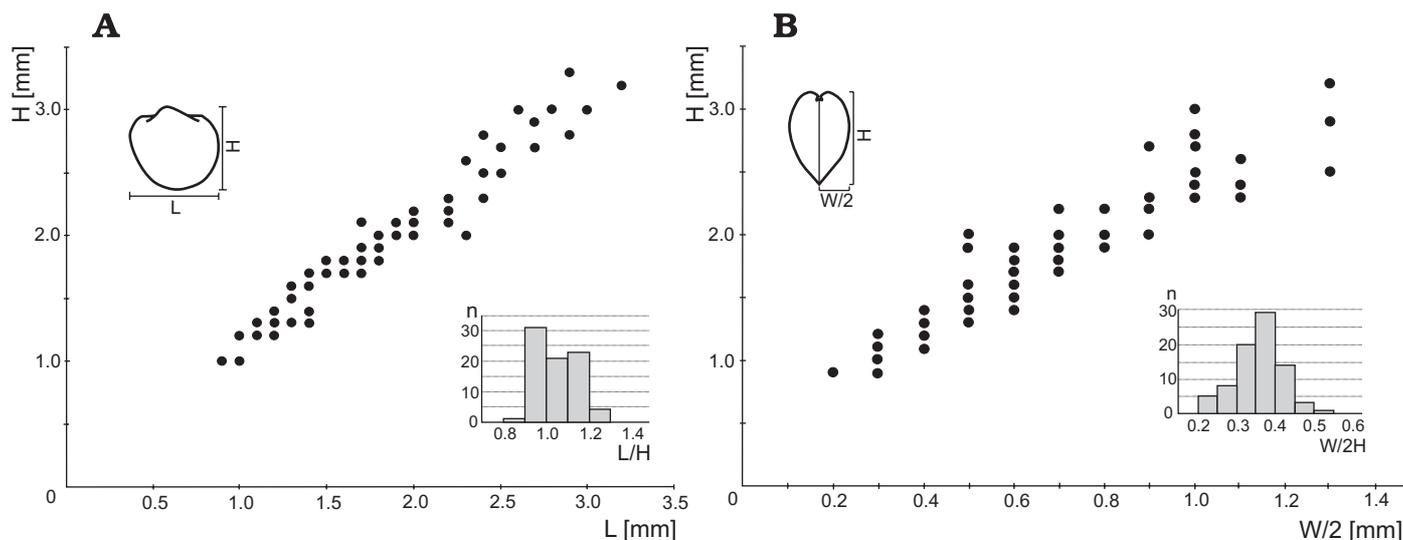


Fig. 8. Distributions of ratios L/H (A) and W/2H (B) indexes of *Glyptohallicardia multicosata* sp. nov. from the Early Frasnian (Szydłówek Beds) at Kostomłoty. Note: some points actually refer to more than one specimen.

furrows. *P. (Bohemozyga) pyritica* sp. nov. also differs by the more convex shape of the whorls and deeper sutures.

Material.—Five pyritised fragments of shells with well-preserved ornamentation (GIUS 4-2284–2287 Kos-14–17).

Description.—Shell is turriculate (to 15 mm in length), dextral, with evolute whorls, which have clearly convex profile. Sutures are moderately deep. Aperture elongate oval. External and internal lips are not preserved. Ornamentation consists of comparably strong collabral ribs, which are orthocline near the upper suture and then continue to strongly opisthocline ribs to the rounded base where they turn into a prosocline course. Collabral ribs are rounded on the external side of the shell, have a small trench on the internal side, and number 30–32 per whorl. Protoconch not preserved. Axial angle is 20–23°.

Discussion.—Frýda and Bandel (1997) erected a new subgenus for palaeozygopleurids with characteristic ornamentation consisting of strongly opisthocline collabral ribs, reflecting the shape of the internal lip. In contrast to shells of *Katoptychia* Perner, 1907, with a similarly strong opisthocline external lip, *Palaeozygopleura (Bohemozyga)* is characterised by the appearance of ornamentation already at the earliest stages of ontogeny in teleoconchs, a more convex profile of the whorls, and a smaller-sized protoconch (see Horný 1955; Frýda and Bandel 1997).

Occurrence.—At the type locality, Kostomłoty II quarry (Małe Górki) and also from the Early Frasnian Kadzielnia limestones from Jaźwica (set J; see Krawczyński 2006) near Kielce (Holy Cross Mountains, Poland).

Superfamily Subulitoidea Lindström, 1884

Subulitidae indet. (Fig. 5D).—Two pyritised internal moulds with preserved protoconchs have been collected. Subulate

shell with partially preserved growth lines and characteristic non-archaeogastropod protoconch, openly coiled in the earliest ontogenetic stages, suggests that these belong to family Subulitidae Lindström, 1884 (see Frýda and Bandel 1997; Frýda and Manda 1997). A more precise identification is not possible because of the absence of diagnostic features. Representatives of subulitids are common in the various facies of Givetian and Frasnian age in the Holy Cross Mountains, where they have been reported from open-shelf settings (Jaźwica Member, Late Givetian; see Racki 1988) as well as from reef facies (upper Szydłówek Beds, Early Frasnian; see Krawczyński 1998). Specimens preserving their protoconchs are known only from the Goniatite Level at Kostomłoty.

Class Bivalvia Linnaeus, 1758

Order Arcoidea Stoliczka, 1871

Family Buchiolidae Grimm, 1998

Genus *Glyptohallicardia* Grimm, 1998

Type species: Cardium palmatum Goldfuss, 1837 (Goldfuss 1837: 207, pl. 143: 7), the Frasnian, Germany.

Glyptohallicardia cf. *palmata* (Goldfuss, 1837) (Fig. 6K).—

A single pyritised internal mould of a shell with poorly preserved hinge margin has been found in Goniatite Level at Kostomłoty. *Buchiola (Buchiola) retrostriata* (von Buch, 1832) has a very similar ornamentation but there are more radial ribs (15–21), a lower shell and a smaller anterior part (see Kříž 2004). The most important features differentiating both taxa are the clearly larger anterior part of ligament in *G. palmata* (see Grimm 1998). The present specimen has the dorsal portion of the shell almost invisible and it is impossible to determine the size of the ligament. Kříž (2004) suggested that *B. retrostriata* has a larger number of radial ribs (16–17) than *G. palmata* (12–14). For that reason, the present specimen is referred with a query to *G. palmata*. Widely

distributed in the European Frasnian, with records from Great Britain (Babin 1963), the Ardennes (Belgium) (Mailieux 1936), Rhenish Slate Mountains (Goldfuss 1837; Beushausen 1895), Harz (Roemer 1850; Clarke 1885), and also in Sudetes Mountains (Gunia 1968; see also Grimm 1998).

***Glyptohallicardia ferruginea* (Holzapfel, 1895)** (Fig. 6M–O).—Three pyritised fragments of internal shell moulds with well-preserved ornamentation have been collected. This taxon is on record from Eifelian to Early Frasnian (*Pa. transitans* conodont Zone; see Grimm 1998). *Glyptohallicardia ferruginea* has been recorded from Devonian strata in Great Britain (Babin 1966) and the Rhenish Slate Mountains (Holzapfel 1895; Beushausen 1895), as well as from North America (Clarke 1904; see also Grimm 1998). This species also was reported by Sobolev (1909) from Frasnian of the Holy Cross Mountains.

***Glyptohallicardia* aff. *G. conversa* (Clarke, 1904)** (Fig. 6G–J).—Six well-preserved and four fragments of pyritised internal moulds have been collected at Kostomłoty. Ornamentation and shape of the shell are most similar to the features characterising *G. conversa*, which has 16–17 radial ribs. The Kostomłoty specimen differs by a clearly larger number of radial ribs. *Glyptohallicardia conversa* is known from Frasnian strata and probably ranged into the latest Givetian of North America (Clarke 1904; Clarke and Swartz 1913; see also Grimm 1998).

***Glyptohallicardia multicostata* sp. nov.**

Fig. 6A–F.

Holotype: GIUS 4-2290 Kos-20 (Fig. 6A).

Type horizon: Goniatic Level at the uppermost part of the Szydłówek Beds; *Palmatolepis transitans* conodont Zone, Early Frasnian.

Type locality: Active quarry Kostomłoty II (Małe Górki).

Derivation of the name: From Latin *multus*—numerous and *costa*—rib.

Diagnosis.—*G. multicostata* sp. nov. markedly differs from species with similar shell proportions, such as *G. conversa*, *G. palmata*, *G. ruppachensis* (Beushausen, 1895), *G. eifeliensis* (Beushausen, 1895), and *G. aquarum* (Holzapfel, 1895), as well as from other species of the genus *Glyptohallicardia* by a much larger number of radial ribs (24–29) on the shell surface.

Material.—Eighty well-preserved and almost 120 fragments of pyritised internal moulds and two internal moulds with preserved fragments of shells (GIUS 4-2290 Kos-20, 4-2291 Kos-21, 4-2292 Kos-22, 4-2579 Kos-46/1–2, 4-2847 Wz-41a/1).

Description.—Shell equivalve, inequilateral, moderately small (dimensions of holotype (mm): height = 2.5; length = 2.7; width/2 = 1.0), strongly inflated, ovate in outline and slightly elongated towards the postero-ventral margin. Prosoyrate umbilicus moderately large, slightly anterior in position. Hinge margin long, straight without visible hinge teeth. Ligament area narrow posteriorly and enlarged nearly triangular anteriorly. Ornamentation consists of 24–29 radial ribs slightly curved towards the anterior. Ribs are a little rounded on internal moulds and faintly flattened on ex-

ternal shell surface. On the surface of the ribs, on older shell portions, there are medium-sized, rounded tubercles as a result of crossing ribs by growth lines. Tubercles disappear at the ventral margin and delicate rounded chevrons replace them. Interspaces are narrower or have the same width as the ribs.

Discussion.—The large ligament area anteriorly suggests this species to belong to the genus *Glyptohallicardia*. On two specimens, remains of the shell are preserved, but ornamentation is weak and obliterated. Thus the above description is based on internal moulds. Within the population of these bivalves there is no strong differentiation in shell shape, defined by the ratios L/H and W/2/H. The average value of L/H is 1.07, while W/2/H = 0.36 (Fig. 8).

Occurrence.—Known exclusively from the type locality and coeval deposits from Ściegna section (Łysogóry region; Penczek 1995).

Order Praecardioida Newell, 1965

Family Antipleuridae Neumayr, 1891

?***Cabricardium* sp.** (Fig. 6P–Q).—Three pyritised internal moulds with poorly preserved dorsal portions have been found in the Goniatic Level. They have umbones clearly less tumid than from material described by Kříž (2004). However, the oval shell shape and ornamentation typical of the genus, consisting of delicate radial ribs crossed by convex commarginal bands suggests that this probably is a member of *Cabricardium*. Species of this genus described by Kříž (2004) come from the Montagne Noire (France) deposits of Late Frasnian and Early Famennian age.

Order Pterioda Newell, 1965

?Family Lunulacardiidae Fischer, 1887

?***Metrocardia* sp.** (Fig. 6L).—A single pyritised internal mould with poorly preserved dorsal portion has been studied. The present specimen is characterised by a dominance of radial ornamentation which consists of delicate furrows crossed by weaker commarginal lines. The subcircular shell shape suggests it belongs to *Metrocardia*; however, the poorly preserved dorsal portion of the shell with lunule makes that the identification is imprecise. *Metrocardia* described by Kříž (2004) come from sediments of Early Frasnian and Early Famennian age.

Family Pterineidae Miller, 1877

***Leptodesma* sp.** (Fig. 6R).—A single pyritised internal mould has been found. The characteristic shell shape, the long and simple hinge margin and medium-sized prosogyre top suggest it is assignable to *Leptodesma*. However, the absence of diagnostic features on this internal mould of a juvenile shell, e.g., ornamentation, makes recognition of the species difficult. *Leptodesma* has a worldwide distribution in late Palaeozoic (see Cox et al. 1969).

Conclusions

The Early Frasnian fauna of the Goniatite Level at Kostomłoty is dominated by juvenile orthoconic cephalopods and goniatitids, but only two genera (*Acanthoclymenia* and *Linguatormoceras*) have been conclusively identified. On the other hand, sufficiently well-preserved assemblages of gastropods and bivalves allowed the recognition of four gastropod taxa (including one new species) and seven species of bivalve, also including one new.

In the deep-water, stagnant and oxygen-deficient Kostomłoty basin, an inception stage of major geochemical perturbation in carbon cycling (Yans et al. in press; see also Pisarzowska et al. 2006) is recorded as an episode of probably high productivity and a stressful benthic habitat under conditions of overall sediment starvation due to significantly reduced carbonate production in the Dyminy Reef complex (Racki et al. 2004; Pisarzowska et al. 2006). The resultant faunal assemblage, rich in goniatitids and styliolinids, document episodic and perhaps localized blooms; pelagic biota predominate, but obviously allochthonous elements such as gastropods and amphiporoids occur as well. These latter must have been transported into the deeper settings during sea-level rise and flooding of fringing reefs (Timan Event) and/or storm events, and there were mixed with typically pelagic forms. It could also work the other way around. Sea-level rise leads to flooding of nearby areas, and thus to introduction of pelagic material (in this case: juvenile cephalopods) into reefal settings, and then back to the deeper water again by this hypothesized quasi-estuarine circulation of water masses. Thus, more generations (i.e., over a longer time period) might have been mixed – after all this event (or set of events) must have lasted for a longer period for it to form a level of 1.6 m thickness!

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