Crinoid assemblages in the Polish Givetian and Frasnian

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Givetian and Frasnian crinoid faunas of the Holy Cross Mts and Silesia-Cracow Region are arranged in fourteen assemblages. Their diversity decreases generally from northern to southern regions reflecting crinoid habitat differentiation during either platform or reef phases of facies development. Distributional patterns are superimposed on a six-step general succession of the faunas which was mainly controlled by environmental changes related to eustatic cycles. Nine crinoid species have been identified by calyces, thirteen species are based on stems attributed to calyx genera, and forty-eight kinds of columnals, probably representing distinct species, are classified within artificial supraspecific units. Of them thirteen are new: Anthinocrinus *brevicostatus* sp. n., *Asperocrinus* brevispinosus sp. n., Calleocrinus bicostatus sp. n., *Calleocrinus kielcensis* sp. n., *Exaesiodiscus compositus* sp. n., *Kasachstanocrinus tenuis* sp. n., *Laudonomphalus pinguicostatus* sp. n., *Noctuicrinus? varius* sp. n., Ricebocrinus *parvus* sp. n., *Schyschcatocrinus delicatus* sp. n., Schyschcatocrinus *multiformis* sp. n., Stenocrinus *raricostatus* sp. n., and *Urushicrinus* perbellus sp. n.

Key words: crinoids, palaeoecology, Devonian, Poland.

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Introduction

Givetian and Frasnian crinoid remains from southern Poland, despite their wide distribution and frequent rock-building significance, have not been a subject of comprehensive studies until now. Scarce data on crinoid occurrences in the Holy Cross Mountains are dispersed in older works (Zeuschner 1869; Gurich 1896; Sobolev 1909) where representatives of four genera [Cupressocrinites, Haplocrinites, *Hexacrinites*, and *Rhipidocrinus*) were reported. The subject of greatest interest has been the rich crinoid fauna of the Skały Beds, the type stratum for five species (Kongiel

1958; Piotrowski 1977; Głuchowski 1980a), though still inadequately recognized (see Gluchowski 1980b, 1981c, 1982).

Despite the scarcity of articulated skeletons, isolated stem fragments, may allow us to recognize species diversity and faunal dynamics of fossil crinoids. In previous papers (Gluchowski 1981a, b) I identified more than 30 crinoid colurnnal species from 14 localities, chiefly Givetian in age.

The present study deals with many new sites in the Holy Cross Mountains and Silesia-Cracow Region. Discoveries of more complete crinoid specimens with crowns or calyces are particularly important. The number of identified species has increased to 70. This enables relatively detailed analysis of crinoid faunas diversity in respect to their paleoecologic and stratigraphic distribution.

The collection is stored at the Laboratory of Paleontology and Stratigraphy, Silesian University in Sosnowiec (Catalogue Symbol GIUS-4) and at the State Geological Institute in Warsaw (Catalogue Numbers IG 163 II 18 and IG 169 II 19).

Paleogeographic and stratigraphic setting

The paleogeographic subdivision of the western Holy Cross area into five units is taken from Racki (1993), which is a modification of the scheme developed by Szulczewski (1977). At present, Racki (1993) subdivides the southern Kielce carbonate platform into four subregions: Northern, Central, Southern and Chęciny-Zbrza. The broadly-defined intrashelf basin in the north is composed of quite different north-eastern (Łysogóry) and western (Kostomłoty) parts. Additionally, the faunas of the eastern part of Holy Cross Mountains are considered to represent a separate unit.

The studied crinoids are derived from forty localities in the Holy Cross Mountains (Fig. 1), and two from the Silesia-Cracow Region. For diversity of analysis sixty samples have been selected from well defined lithological horizons. The stratigraphic position of the samples (Fig. 2) has been established owing to recent conodont datings by Racki (1993 and unpublished data) and Racki & Bultynck (in preparation). Details are also contained in the 'Register of Localities' of Racki (1993), and only supplementary remarks, mostly for the northern areas, are given below.

The stratigraphically oldest fauna have been recovered from the Skały Beds at their type section, from the complexes XVI-XXIII of Pajchlowa (1957). This very fossiliferous site is of latest Eifelian through Early Givetian age, corresponding to the conodont P. *ensensis* Zone and Early P. ***varcus*** Subzone (Malec 1984; Malec in Sarnecka 1988). The succeeding Świętomarz Beds, sampled for crinoids and conodonts at the type locality, in the transition interval between the Skały and Nieczulice Beds, represent the Early *P.* ***varcus*** Subzone (Kłossowski 1985).

Givetian crinoids from the Laskowa Gora Quarry near Kostomłoty are represented by a bulk sample for set A of Laskowa Gora Beds (see Racki

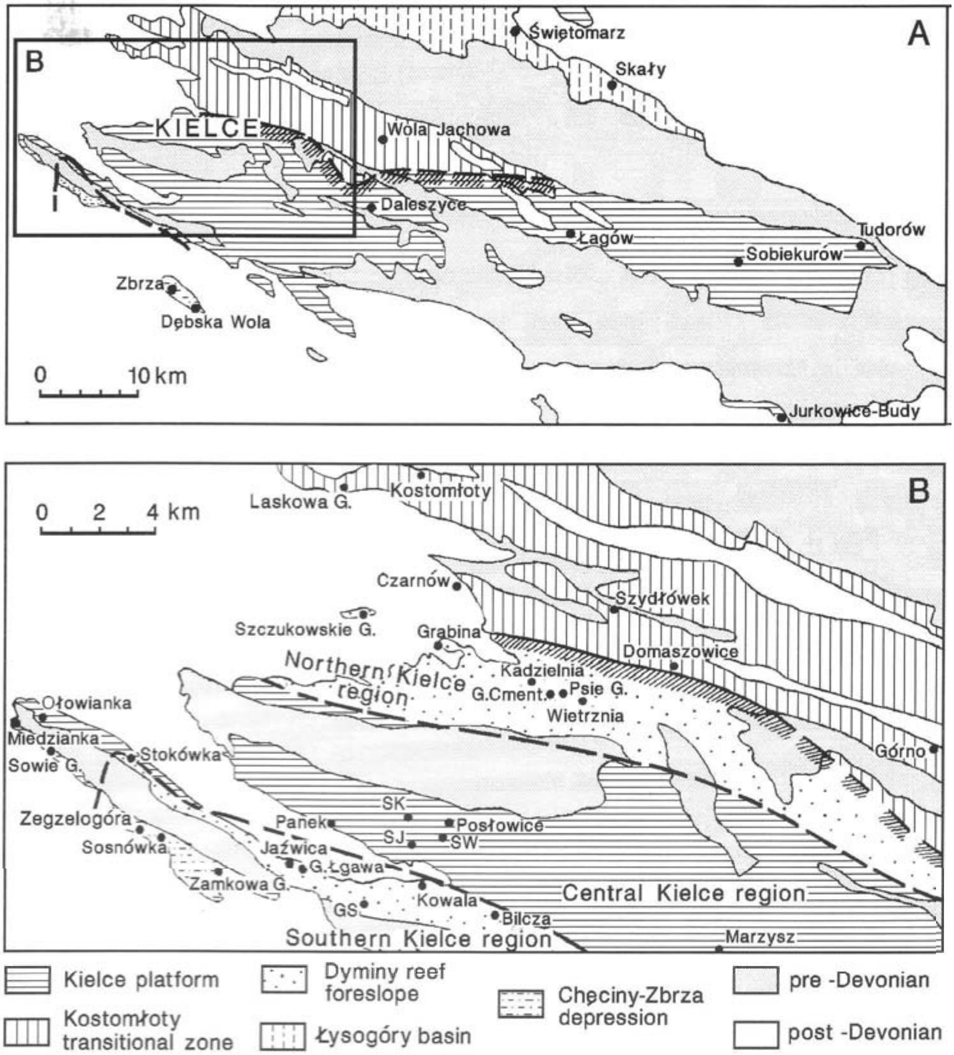


Fig. 1. Map of the crinoid localities in the Holy Cross Mts, against late Givetian (A)and early Frasnian (B) paleogeographic scheme (after Racki 1993: Fig. 2); edge of the Kielce platform hatchured. Abbreviations: SK – Sitkówka-Kostrzewa, SW – Sitkówka-Kowala, SJ – Sitkowka-Jaźwica, GS – Góra Sołtysia.

et al. 1985). It is assumed that the oldest specimens come from the *S. hermanni* Zone, but *an* admixture from the higher part of the *P. varcus* Zone is also possible due to the poor recognition of a boundary between these zones (Racki 1985a). The youngest crinoid fauna in the Kostomloty Region were recovered from the higher part of the Kostomloty Beds (sets F–H *sensu* Racki 1993; Frasnian to Famennian transition beds) cropping out in a small overgrown rural quarries at the Kostomloty hills. Frasnian crinoids were also collected from the eastern part of the Szczukowskie

Górki Quarry (detrital limestones in the lower part of section) in the Northern Kielce Region and from Tudorow (detrital parts of the section) in the Eastern Region (Godefroid & Racki 1990). Moreover, Late Frasnian micritic limestones, locally enriched in crinoids, were sampled in a small overgrown outcrop on a hill west of Daleszyce, in the Northern Kielce Region.

The crinoid faunas Gom the important Kowala section in the Southern Kielce Region come from the railway cut (set C), Wola Quarry (sets D–G) and road cut (set H). Crinoid remains from the Dębnik anticline were found in the Debnik Limestone (=set A), and Grained Limestone (=set D), exposed in the Old Carmelitan Quarry and reached by the borehole Dębnik 2-7, respectively (see Narkiewicz & Racki 1984).

Status of the crinoid stems taxonomy

Paleozoic crinoid stem fragments, in spite of their abundance in shallow-water fossil sediments, remain still poorly known. In descriptions of calyces only rarely is attention paid to associated columnals. Little is known also about the morphological variability along the stem. There is doubt that most of the crinoid species differ in stem morphology within particular fossil assemblages. It is also probable, that similar stems found in geographically and stratigraphically different localities may belong to completely unrelated species. Therefore, the basic question that remains to be answered, is whether, and to what degree, it is possible to recognize crinoid biological species on the basis of stem morphology. Some distinctive crinoid stem fragments can be classified reliably at the genus level, but only exceptionally is their morphology diagnostic for a species (see Moore & Jeffords 1968; Le Menn 1985). Examples of genera which are safely recognized herein are *Ammonicrinus*, *Myelodactylus*, *Gilbertsocrinus*, *Platycrinites* as well as *Melocrinites* and *Cupresocrinites*. Two others, *Eutaxocrinus* and *Parahexacrinus*, are highly probable.

In the present paper, stem-based species are understood as biological units and treated according to the recommendation of the ICZN. It seems that in many cases species level columnal taxonomy is sound biologically, enabling us to potentially match stems with crowns in type localities. On the other hand, supraspecific columnal taxonomy concerning previously undescribed genera has little chance to express the true evolutionary relationships. Whenever it is possible columnals were classified within crown-based genera. In remaining cases, earlier introduced higher rank units are used provisionally but not included in ordinal rank classification (for discussion see Moore & Jeffords 1968). Measurable morphological characteristics of columnals follow those of Moore *et al.* (1968).

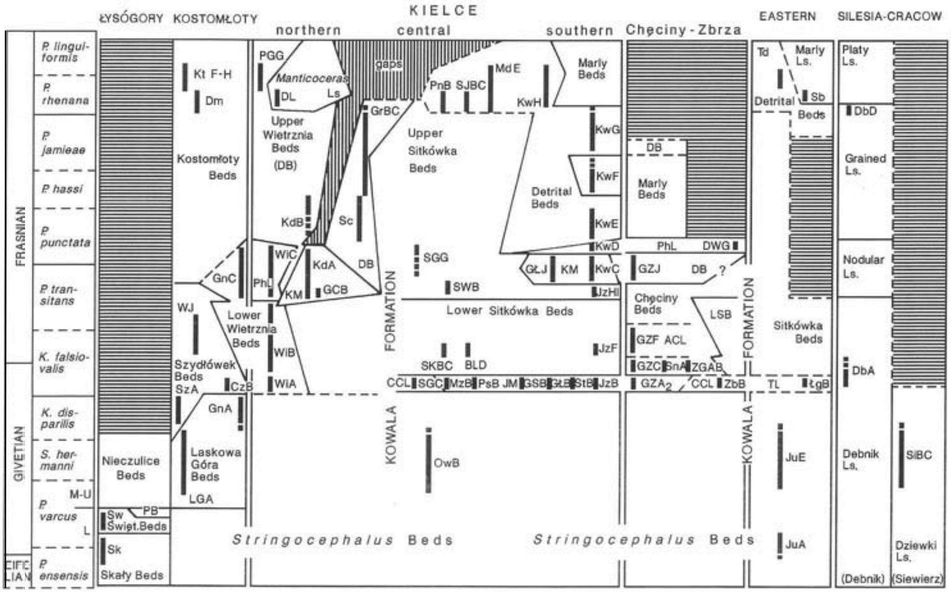


Fig. 2. Stratigraphic setting of the crinoid samples; paleogeographic-stratigraphic subdivision and correlation adopted from Racki (1993: Fig. 3). Abbreviations: ACL – Atrypid-Crinoid Level, CCL – Crinoid-Coral Level, DB – Detrital Beds, JM – Jaźwica Mbr., KM – Kadzielnia Mbr., LSB – Lower Sitkowka Beds, PB – Pokrzywianka Beds, TL – Tenticospiriier Level; Sk – Skały, Sw – Świętomarz, LG – Laskowa Góra, Kt – Kostomłoty, Sz – Szydłówek, Cz – Czarnów, Gn – Górno, WJ – Wola Jachowa, Dm – Domaszewice, Wi – Wietrznia, Kd – Kadzielnia, GC – Gora Cmentarna, PG – Psie Górki, DL – Daleszyce, Sc – Szczukowskie Gorki, Gr – Grabina, Ow – Ołowianka, SG – Sowie Górki, Mz – Marzysz, Ps – Poslowice, SK – Sitkówka-Kostrzewa, SW – Sitkówka-Kowala, Bl – Bilcza, Pn – Panek, SJ – Sitkówka-Jaźwica, Md – Miedzianka, GS – Góra Sołtysia, GŁ – Góra Łgawa, St – Stokówka, Jz – Jaźwica, Kw – Kowala, GZ – Góra Zamkowa, Zb – Zbrza, Sn – Sosnowka, ZG – Zegzelogora, DW – Dębska Wola, Ju – Jurkowice-Budy, Łg – Łagów, Td – Tudorów, Sb – Sobiekurów, Si – Siewierz, Db – Dębnik.

Taxonomic review of the fauna

Family Melocrinitidae d'Orbigny 1852

Melocrinites cf. gibbosus Goldfuss 1831 (Fig. 3I–K). — The collected crowns are incompletely preserved. Differentiated convexity of calyx plates is observed in various specimens. An articular surface fixing the calyx with stem is bordered by fine and very short culmina. Occurs in Late Frasnian Detrital Beds (Sitkówka-Jaźwica BC, Miedzianka E, Kowala G). M. *gibbosus* was reported from the Eifelian (Gerolstein, Kerpen) and ?Frasnian (Goniatitenkalk of Herborn) of Germany (Goldfuss 1831; Schultze 1867; Koenen 1886).

***Melocrinites* cf. hieroglyphicus Goldfuss 1831** (Fig. 3L–M). — Crowns studied are incomplete, and articular facets of columnal and brachial connections are not preserved. Individual cup plates are less inflated than in M. cf. gibbosus, and their specific surface sculpturing is very weakly visible. Occurs in the Late Frasnian Detrital Beds (Kowala G). M. *hieroglyphicus* is known from the Frasnian of Germany (Stolberg) and Belgium (Senzeille) (Goldfuss 1831; Koenen 1886).

Melocrinites sp. (Fig. 3A–H).— Heteromorphic stems with most proximal part characterized by two-order columnals slightly expanded near calyx (Fig. 3C). In the middle(?) part of the column there are columnals of several orders, and the lower order columnals cover completely those of higher orders (Fig. 3D, F). Root-type attachment structures (Fig. 3E) are observed in the most distal part. Articular facets of columnals from different parts of the stem exhibit some variability in number and thickness of culmina which are distinctly longer than those of M. cf. gibbosus. The columnals derived from proximal and central fragments of the column are similar to Melocrinites pergrandis (Dubatolova 1964) from the Frasnian of the Kuznieck Basin. However, stems of such kind may belong to different species of the genus. Also, isolated fragments of biserial, secondarily fused arms (Fig. 3G–H) are without significant diagnostic value below the genus level. Occurs in the Late Frasnian Detrital Beds (Grabina BC, Sitkówka-Jaźwica BC, Panek B, Miedzianka E, Kowala F, G).

Family Hexacrinitidae Wachsmuth & Springer 1885

***Hexacrinites* sp.** (Fig. 4A–F).— Calyces are poorly preserved and incomplete. The anal opening is located eccentrically (closer to the anal plate), on a relatively high tegmen. Anal plate is narrow, placed between radial plates. Primibrachial reduced, completely covered with first two secundibrachials partly joined with radial plate (Fig. 4A–B). Occurs in the Late Frasnian Detrital Beds (Sitkówka-Jaźwica BC, Kowala H).

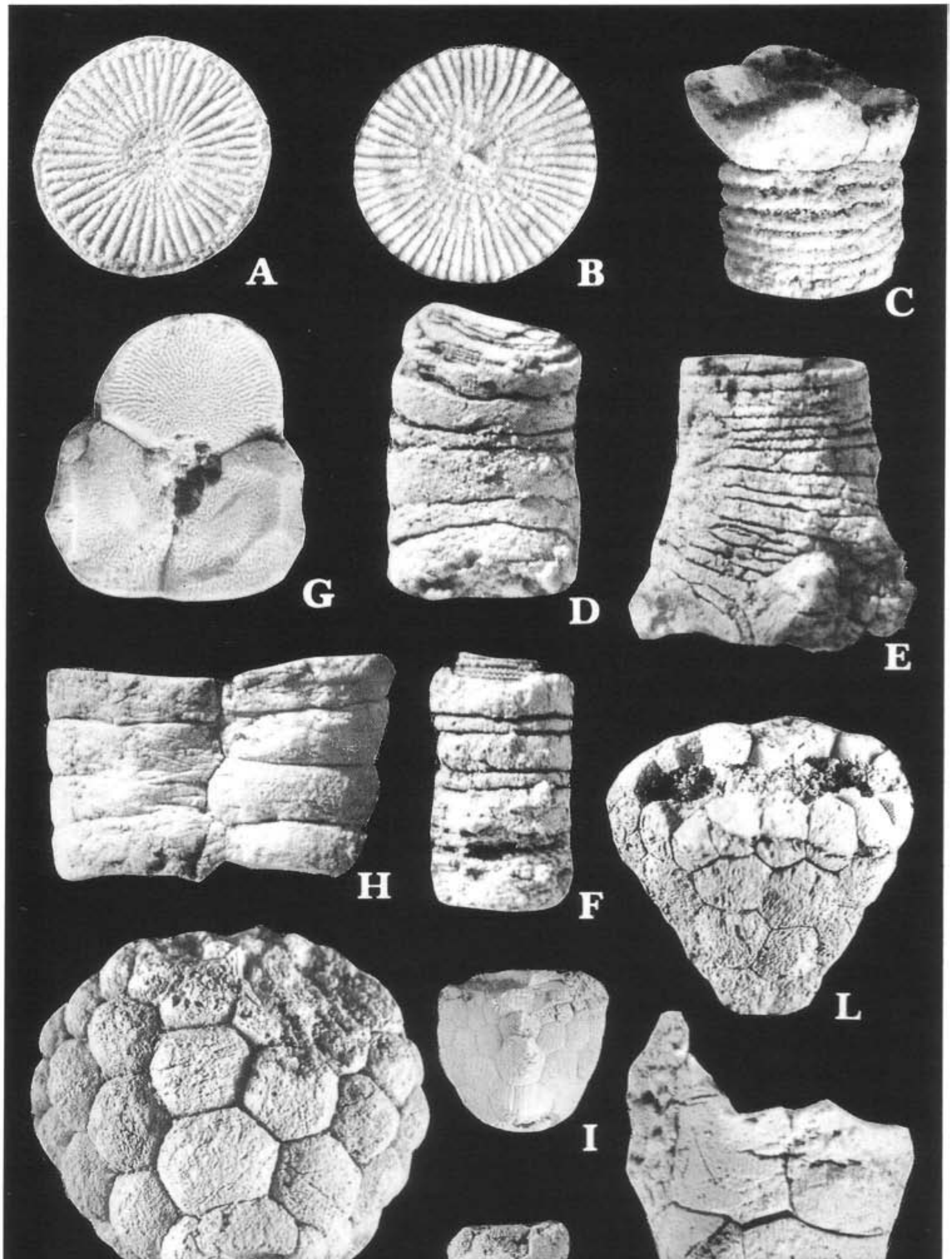
Family Platycrinitidae Austin & Austin 1842

Platycrinites *minimalis* Głuchowski 1980 (Fig. 4J).— Narrow furrow surrounding articulum is invisible in some newly collected specimens, and delicate fulcral ridge is only weakly developed. The species occurs in the Eifelian-Givetian passage Skały Beds (Skały).

Platycrinites sp. (Fig. 4K).— Completely smooth articular facet and relatively greater lumen size distinguish these rare columnals from P. minimalis. Occurs in the Givetian Laskowa Gora Beds (Gorno A), Early Frasnian Lower Wietrznia Beds (Gorno C), and Phlogoiderhynchus Level (Wietrznia C).

Platycrinites? sp. (Fig. 4L–N).— Columnals of this kind are atypical for Platycrinites in having differently developed opposite articular facets. One facet is oval-shaped, with a visible fulcral ridge and delicate marginal crenularium; the other surface is slightly oval to almost circular, bordered by prominent crenularium composed of thick rare culmina, and without

Fig. 3. ❑A–H. Melocrinites sp.; A–F. Stem fragments GIUS-4-200/3-8, x 5. G–H. *Arm* fragments GIUS-4-200/31-32, x 7, Kowala G, Detrital Beds, Late Frasnian. ❑I–K. Melocrinites cf. gibbosus Goldfuss 1831; I, K. Cups IG 163 11/ 18–19 in D ray (I) and ?AB interray (K) views, Sitkówka-Jaźwica BC, Detrital Beds, Late Frasnian, x 2.5. J. Cup GIUS-4-200/2 in D ray



view, Kowala G, Detrital Beds, Late Frasnian, x 2.5. ❑L, M. *Melocrinites* cf. hieroglyphicus Goldfuss 1831; cups GIUS-4-200/15-16 in BC interray (L), x 3, and AE interray (M) views, x 5, Kowala G, Detrital Beds, Late Frasnian.

any fulcral ridge. Occurs in the Givetian Laskowa Gora Beds (Gorno A) and Early Frasnian Lower Wietrznia Beds (Gorno C).

Family Parahexacrinidae Schewtschenko 1967

***Parahexacrinus?* sp.** (Fig. 4H–I).— The columnals are distinct from the typical representatives of the genus (see Schewtschenko 1967: p. 77; Milicina 1977: p. 130) in having rarer and thicker culrnina on the articular facet. In some aspects they resemble stems of *Amonohexacrinus* (Schewtschenko 1967: p. 82) and of *Melocrinites pyramidalis* Goldfuss (Schultze 1867: p. 178, Pl. 6: 5). Occurs in the Late Frasnian Detrital Beds (Grabina BC, Sitkówka-Jaźwica BC, Kowala G, H).

Family Dichocrinidae S.A. Miller 1889

***Eocamptocrinus fragilis* Gluchowski 1980** (Fig. 4G).— All columnals reveal slightly reduced height (thickness) from the side of eccentrically-placed lumen which suggests a natural curvature of the delicate stem. The species occurs in the Eifelian-Givetian passage Skaly Beds (Skaly).

Family Polypeltidae Angelin 1878

***Trybliocrinus* sp.** (Fig. 5K–M).— Articular facets of the columnals are characterized by distinct channels projecting radially from the lumen; their traces on the lateral side are recognizable as fine pores. A relatively smaller lumen makes these specimens different from other representatives of the genus. Occurs in the Givetian Laskowa Gora Beds (Laskowa Gora A).

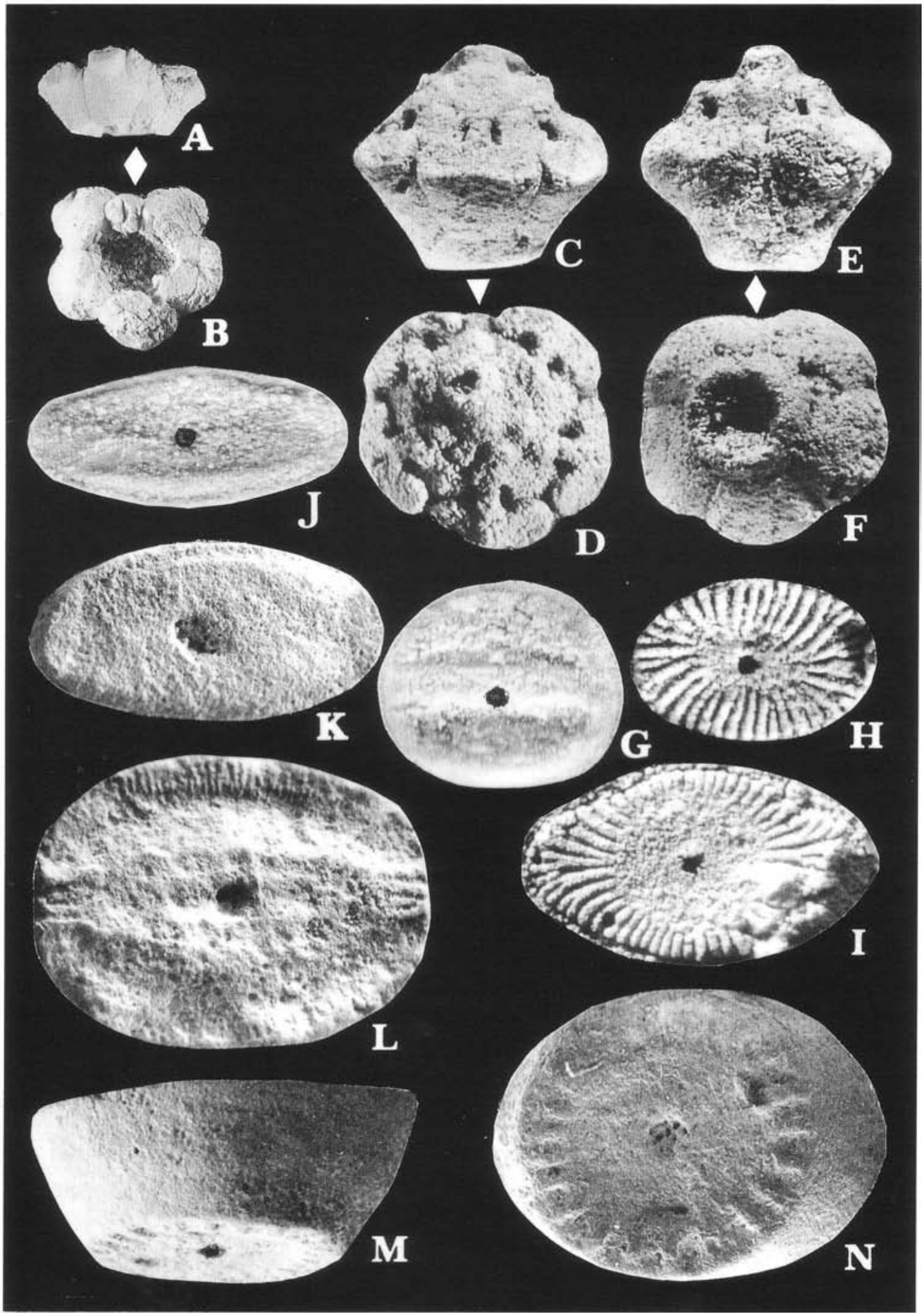
Family Rhodocrinitidae Roemer 1855

***Gilbertsocrinus vetulus* Moore & Jeffords 1968** (Fig. 5H–I).— All stem fragments show a characteristic, distinct curvature. It is possible that the column was recumbent on the bottom in 'coiled' position, and only its proximal part kept the crown above the sediment surface. Occurs in the Eifelian-Givetian passage Skały Beds (Skaly). The species was first described from the Erian (Ludlowville Formation) of New York (Moore & Jeffords 1968).

Family Haplocrinitidae Bassler 1938

***Haplocrinites aremoricensis* Le Menn 1985** (Fig. 5C–G).— Some morphological characters of the calyx, particularly the surface ornamentation of the plates and variability of cup shape, seem to change in the ontogeny of these crinoids (see Le Menn 1985). Occurs in the Givetian Laskowa Gora Beds (Laskowa Gora A, Gorno A) and Szydłówek Beds

Fig. 4. ❑A–F. Hexacrinites sp.; A, B. Cup IG 163 II/18a in posterior [A) and aboral (B) views, Sitkówka-Jaźwica BC, Detrital Beds, Late Frasnian; x 2.5. C–F. Cup GIUS-4-202/15 in anterior (C), oral (D), posterior (E) and aboral (F) views, Kowala H, Detrital Beds, Late Frasnian; x 5. Arrows indicate anal plate. ❑G. Eocamptocrinus *fragilis* Gluchowski 1980: columnal GIUS-4-90/51, Skaly, Eifelian-Givetian passage Skaly Beds; x 23. ❑H–I. Parahexacrinus? sp.; columnals GIUS-4-200/29–30, Kowala G, Detrital Beds, Late Frasnian; x 10. ❑J. Platycrinites *minimalis* Gluchowski 1980; columnal GIUS-4-90/6, Skaly, Eifelian-Givetian passage Skaly



Beds: x 30. OK. *Platycrinites* sp.: columnal GIUS-4-196/5, Gomo A, Laskowa Góra Beds, Late Givetian; x 10. ❑L–N. *Platycrinites?* sp.: columnal GIUS-4-196/6, Gomo A, Laskowa Gora Beds, Late Givetian; x 12.

(Szydłówek A). The species has been reported from the Late Givetian (Kergarvan Formation) of the Armorican Massif, France (Le Menn 1985).

Haplocrinites sp. (Fig. 5A–B).— Cups are smaller than those of H. *aremoricensis* and, despite generally similar shape, they show proportionally higher oral parts. This makes them distinct from other known species of the genus. Calyx plates do not show any surface sculpture. Occurs in the Givetian-Frasnian Lower Wietrznia Beds (Wietrznia B, Gorno C); Early Frasnian *Phlogoiderhynchus* Level (Wietrznia C), and Late Frasnian Detrital Beds (Grabina BC, Kowala H).

Family Myelodactylidae S.A. Miller 1883

Myelodactylus canaliculatus (Goldfuss 1831) (Fig. 5J).— Most columnals collected reveal double cirrial scars, which indicates that they are derived from the proximal part of the stem (see Le Menn 1985: p. 77). Occurs in the Eifelian-Givetian passage Skaly Beds (Skaly). The species has been reported from the Eifelian (Eifel Mountains) of Germany (Goldfuss 1831) and the Eifelian-Givetian (Quelern and Kerbelec Formations) of the Armorican Massif, France (Le Menn 1985).

Family Cupressocrinitidae Roemer 1854

Cupresocrinites sampelayoi (Almela & Revilla 1950) (Fig. 7A–F).— Calyces show varying intensity of brachial surface ornamentation. Furthermore, some specimens have one arm with only 2 (instead of typical 3) brachials (see Fig. 7A). The stem is xenomorphic, triangular, strongly rounded, with a trilobate axial canal. Occurs in the Givetian Laskowa Gora Beds (Laskowa Góra A). The species was reported from the Late Givetian (Portilla Formation of León) of Spain (Almela & Revilla 1950; Breimer 1962).

***Cupressocrinites* cf. *abbreviatus* Goldfuss 1839** (Fig. 6G–H).— Crowns studied are incomplete but marked by prominent surface sculpturing. The stem is massive, tetragonal, rounded, with a large tetralobate axial canal. This species occurs in the Eifelian-Givetian passage Skały Beds (Skały) and Givetian Laskowa Gora Beds (Laskowa Góra A). C. *abbreviatus* has been reported from the Middle Devonian of Germany (Kerpen, Pelm, Gerolstein; Goldfuss 1839; Schultze 1867) and Russia (Karpinskij horizon and *Stringocephalus* Beds of the Urals; Milicina 1977; Polyarnaya 1992).

Cupressocrinites *inflatus* Schultze 1867 (Fig. 6I–J).— Individuals available for study vary in the number of brachials in the arm (7 to 9), as well as in the intensity of the brachial surface ornamentation. Occurs in

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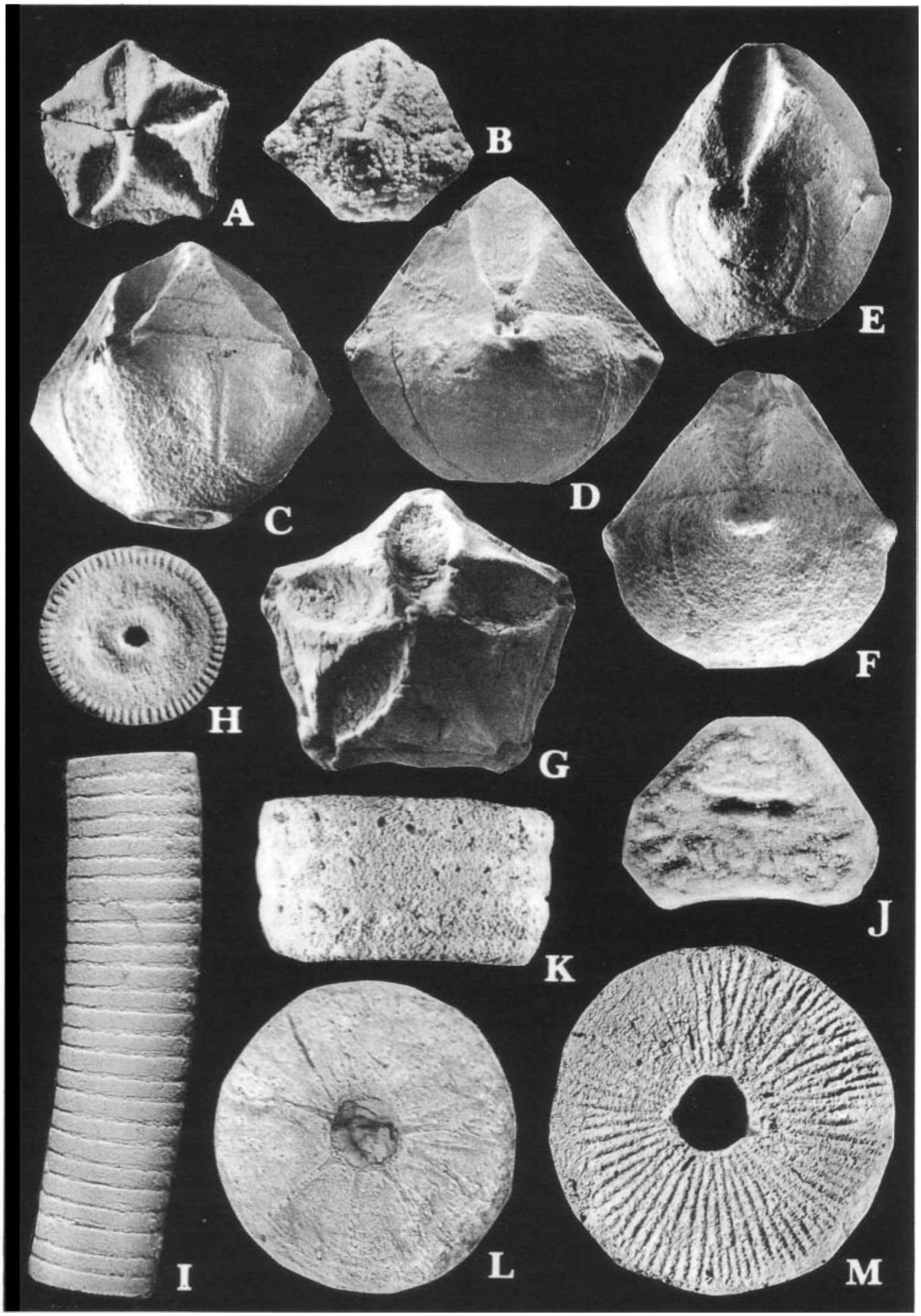
Fig. 5. ❑A–B. Haplocrinites sp.: A. Calyx GIUS-4-404/62 in oral view, Wietrznia B, Lower Wietrznia Beds, Early Frasnian. B. Calyx GIUS-4-202/16 in D ray view, Kowala H, Detrital Beds, Late Frasnian; x 10. ❑C–G. Haplocrinites *aremoricensis* Le Menn 1985; C–E, G. Calyces GIUS-4-318/9–11 in CD interray (C), A ray (D), E ray (E) and oral (G) views, Laskowa Gora A, Laskowa Gora Beds, Givetian; x 10. F. Calyx GIUS-4-196/4 in E ray view, Górno A, Laskowa Gora Beds, Late Givetian; x 10. ❑H–I. *Gilbertsocrinus vetulus* Moore & Jeffords 1968; stem fragments GIUS-4-90/203–204, Skaly, Eifelian-Givetian passage Skaly Beds; x 5. ❑J. *Myelo-*



dactylus canalicatus (Goldfuss 1831); columnal GIUS-4-90/295, Skały, Eifelian-Givetian passage Beds; x 10. OK–M. *Trybliocrinus* sp.: stem fragments GIUS-4-318/12–14, Laskowa Góra A, Laskowa Gora Beds, Givetian; x 3.

the Givetian Laskowa Gora Beds (LaskowaGora A) and Crinoid-Coral Level of the Kowala Formation (Sowie Górki C). The species is known from the Eifelian of Germany (Gerolstein, Pelm, Kerpen; Schultze 1867) and Late Givetian (Portilla Formation of Leon) of Spain (Breimer 1962).

Cupressocrinites gracilis Goldfuss 1831 (Fig. 6C–D).— Species identified on the basis of delicate, tetragonal and rounded stems. Axial canal typically connected by narrow furrows with four peripheral canals. However, some specimens lack the radial connections and in these cases, five independent canals are present. Nodals bear cirral scars. Occurs in the Eifelian-Givetian passage Skaly Beds (Skaly) and Eifelian 'Dąbrowa Limestone' of Grzegorzowice. The species is common in the Middle Devonian of Germany (Eifel Mountains, Pelm; Goldfuss 1831), Russia (Shanda, Mamontovo, and Safonovo horizons of Kuznieck Basin; Conchidiella Zone of the Urals), Kazakhstan, and Tadjikistan (Dubatolova 1971).

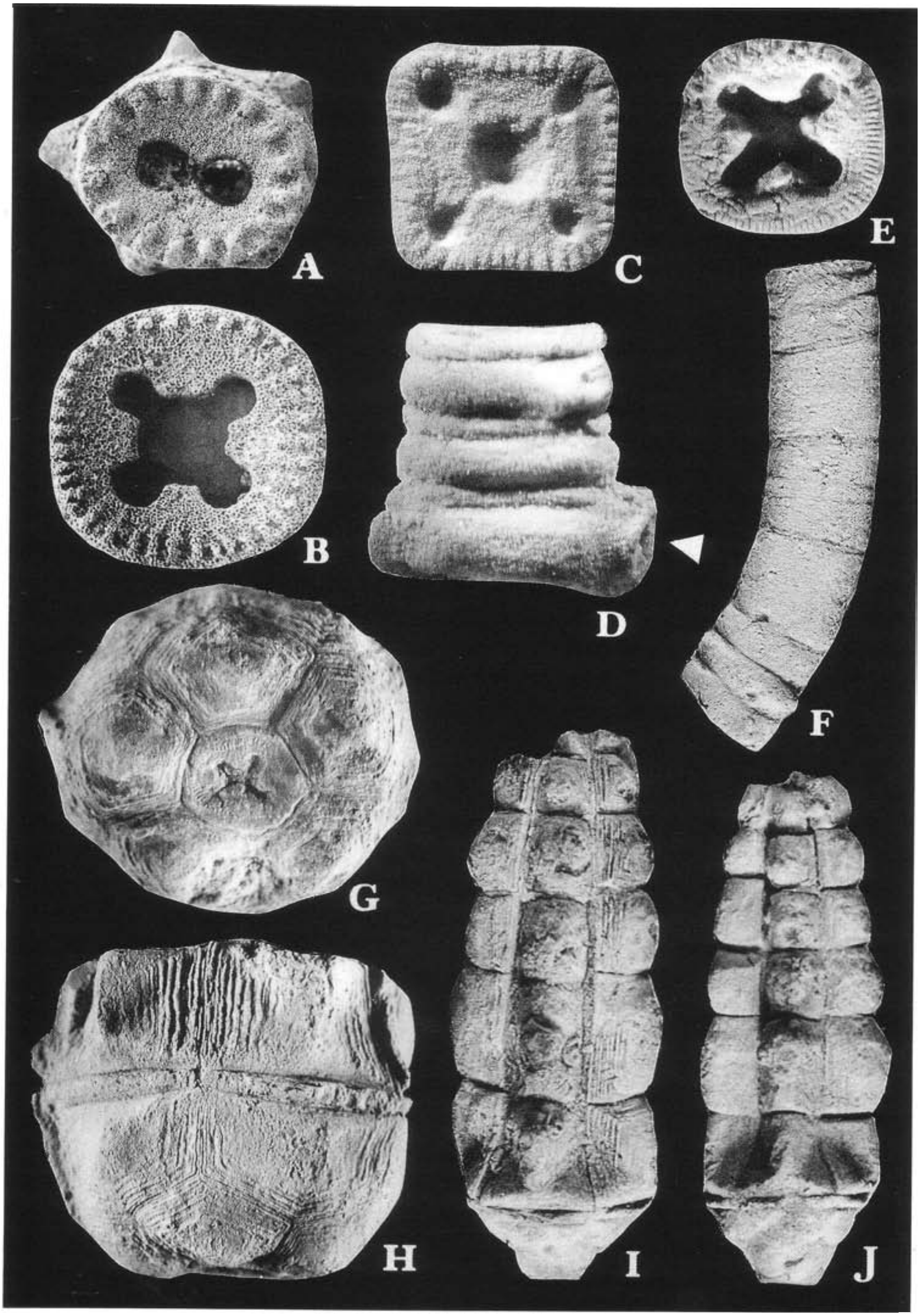
Cupressocrinites sp. A (Fig. 7G).— Stems of the species show similarities to both C. *sampelayoi* and C. *inflatus* but are more triangular in outline. Moreover, the axial canals, commonly trilobate, in some columnals (probably from the distal part of stem) exhibit constrictions in the middle part of the lobes, whereas in other cases these connections, with three peripheral canals, are completely obscured. Similar columnals with a trilobate axial canal occur in the Frasnian of Boulonnais, France where they were described as *Trilobocrinus boloniensis* (Le Menn 1988) but they may belong to Cupressocrinites. Occurs in the Eifelian-Givetian passage Skaly Beds (Skaly), Givetian Laskowa Gora Beds (Laskowa Gora A) and Crinoid-Coral Level (Sowie Górki C), Early Frasnian Lower Wietrznia Beds (Wietrznia B) and the Phlogoiderhynchus Level (Wietrznia C), Late Frasnian Detrital Beds (Kadzielnia B, Szczukowskie Górki, Kowala E).

Cupressocrinites sp. B (Fig. 6A–B).— Coiumnal size and morphology suggest assignement to C. gracilis, but the specimens possess a wide tetralobate axial canal. Connections between central and peripheral canals are enlarged (as in C. abbreviatus). Lateral sides of the nodals bear fine nodes, spines, and cirral scars with 'double' axial canal. The same features characterize the cirrals. Occurs in the Eifelian-Givetian passage Skaly Beds (Skaly), Givetian Laskowa Gora Beds (Laskowa Gora A), Szydlowek Beds (Szydłówek A), Crinoid-Coral Level (Sowie Górki C), and Jaźwica Member (Gora Sołtysia B, Stokowka B, Jaźwica B, Sosnowka A).

Family Taxocrinidae Angelin 1878

***Taxocrinus* sp.** (Fig. 7K–L).– The species is represented by an incomplete calyx with the basal plate obscured and strongly convex radials. Three primibrachials are present in one arm. Some diminutive columnals may belong to the same genus because of the same morphology of their

Fig. 6. Of–B. Cupressocrinites sp. B; A. Cirral GIUS-4-148/1 x 30. B. Columnal GIUS-4-148/2; × 15, Sowie Górki C, Crinoid-Coral Level, Late Givetian. OC–D. Cupressocrinites *gracilis* Goldfuss 1831; Stem fragments GIUS-4-90/205-206, Skaly, Eifelian-Givetian passage Skały Beds: arrow indicates cirrus socket; x 10. OE–H. Cupressocrinites cf. abbreviatus Goldfuss 1839; E–F. Stem fragments GIUS-4-318/5–6; x 3. G–H. Calyx GIUS-4-318/7 in abo-



ral (G) and lateral (H) views: x 2.5, Laskowa Gora A, Laskowa Góra Beds, Givetian. ❏I–J. Cupressocrinites *inflatus* Schultze 1867; calyces GIUS-4-318/27–28, Laskowa Gora A, Laskowa Gora Beds, Givetian; x 1.5.

articular facets to the stem articulation on the base of the cup. Occurs in the Late Frasnian Detrital Beds (Kowala G).

***Eutaxocrinus*? sp.** (Fig. 7J).— These poorly preserved columnals resemble E.? aff. kergarvanensis (Le Menn 1985) but they have longer, sharply pointed spines on lateral sides. Occurs in the Givetian Laskowa Gora Beds (Laskowa Gora A, Gorno A) and Szydlowek Beds (Szydlowek A).

Praeorocrinus polonicus* Gluchowski *1980 (Fig. 7I).— Wide range of variability in colurnnal epifacet size, number, and form of nodes on the lateral sides is notable for this species. In some specimens an irregular keel consisting of joined outgrowths is present. The species occurs in the Eifelian-Givetian passage Skały Beds (Skały) and the Givetian Laskowa Gora Beds (Laskowa Gora A).

Family Calycocrinidae Moore & Strimple 1973

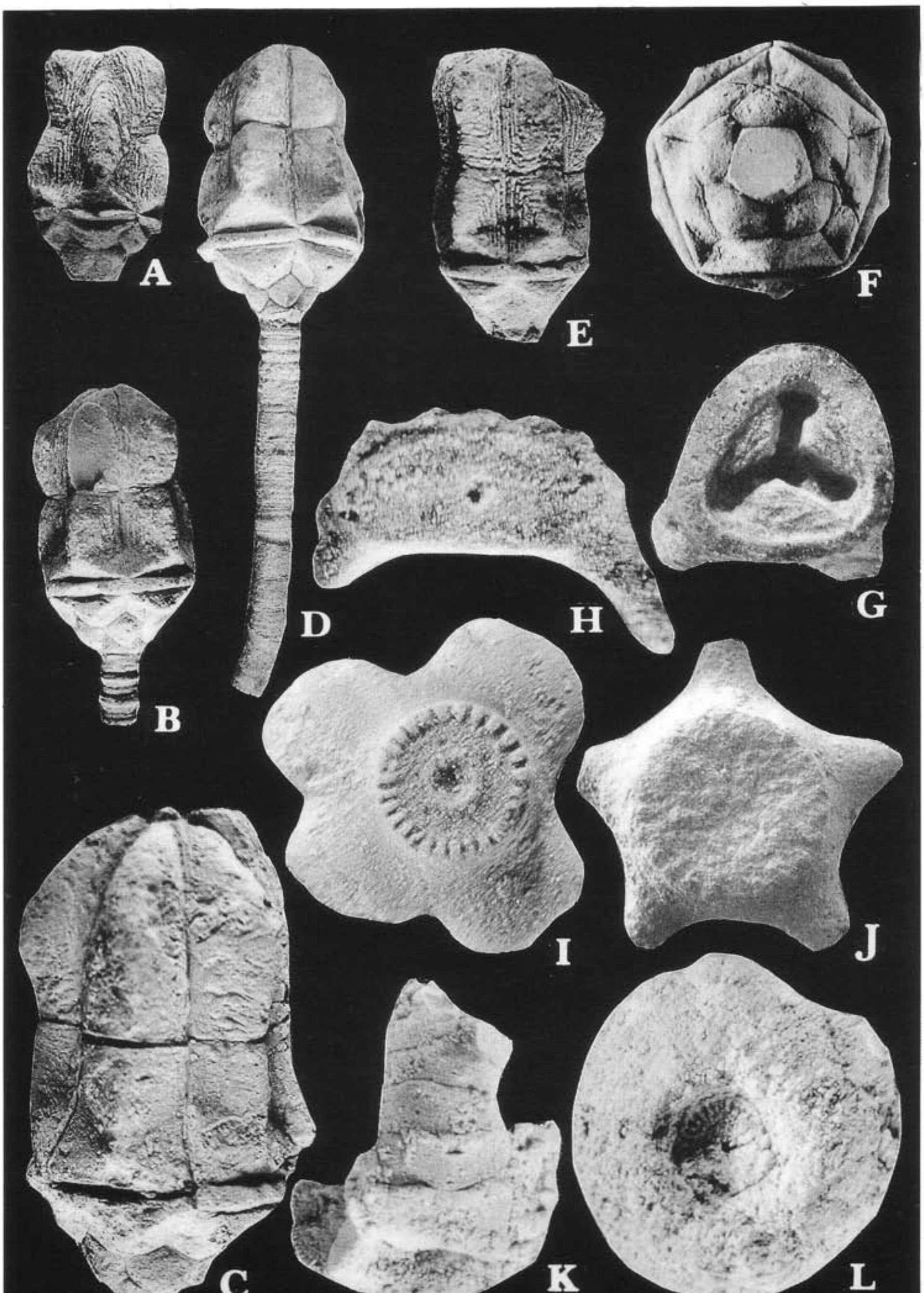
***Ammonicrinus* sulcatus Kongiel 1958** (Fig. 7H).— Columnals forming the proximal part of stem are extensively differentiated in shape and size. A similar variability is also present in the shape of the articular facet and ornamentation on the external surface. The species occurs in the Eifelian-Givetian passage Skały Beds (Skały).

Family 'Anthinocrinidae' Yeltyschewa & Sisova in Schewtschenko 1966

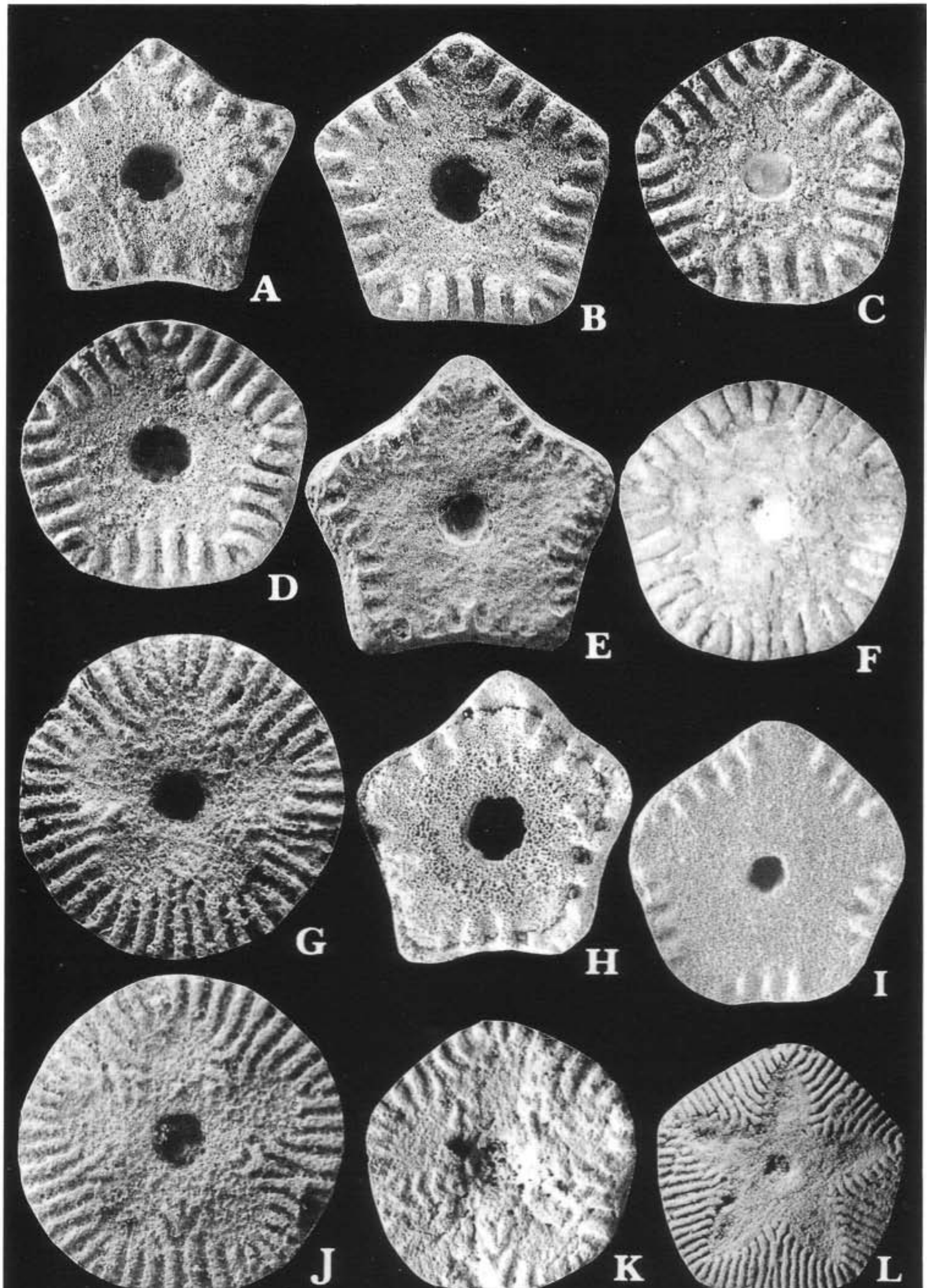
Anthinocrinus primaevus* Sisova in Dubatolova. Yeltyschewa & Modzalevskaya *1967 (Fig. 8G).— The colurnnals are circular with a smooth and slightly convex lateral side. Areola is well-developed, pentalobate, and bordered by straight culmina. Occurs in the Givetian Laskowa Gora Beds (Laskowa Gora A, Gomo A), Szydlowek Beds (Szydlowek A), Crinoid-Coral Level (Sowie Gorki C), and Jaźwica Member (Marzysz B). The species has been reported from the Early and Middle Devonian of Kazakhstan (Sardzhal and Kazakh horizons) and Russia (Salair horizon of the Kuznieck Basin, Kireev and Kuvash horizons of Altai, Bosheneversk to Imatschi horizons of the Amur and Zeya Rivers Basin) (Dubatolova et *al.* 1967; Dubatolova 1971; Stukalina 1991).

Anthinocrinus *wenjukowi* Yeltyschewa *1977* (Fig. 8F).— The columnals are pentagonal, strongly rounded to circular with smooth and slightly convex lateral side. Lumen is pentagonal, medium-sized. Culmina are straight and thick. Occurs in the Early Frasnian Lower Wietrznia Beds (Gorno C), Phlogoiderhynchus Level (Wietrznia C), and Kadzielnia Member (Kadzielnia A, Gora Cmentarna B, Gora Łgawa J). Due to new data, previously mentioned (Gluchowski 1981a, b) a presence of the species in the Fammenian seems doubtful. This species is known from the Frasnian

Fig. 7. ❑A–F. Cupressocrinites *sampelayoi* (Almela & Revilla 1950); calyces GIUS-4-318/16–21 in lateral (A-B, D x 1.5; C x 2.5; E x 3) and aboral (F x 2) views, Laskowa Gora A, Laskowa Gora Beds, Givetian. OG. Cupressocrinites sp. A, columnal GIUS-4-318/31, Laskowa Gora A, Laskowa Gora Beds, Givetian; x 10. OH. Arnrnonicrinus *sulcatus* Kongiel 1958; proximal columnal GIUS-4-90/207, Skaly, Eifelian-Givetian passage Skały Beds; x 10. OI. *Praeorocrinus* polonicus Gluchowski 1980; columnal GIUS-4-90/50, Skały, Eifelian-Givetian passage



Skaly Beds; x 10. ❑J. *Eutaxocrinus*? sp.; columnal GIUS-4-111/1, Szydłówek A, Szydtowek Beds, Late Givetian; x 10. OK–L. *Taxocrinus* sp.; calyx fragment GIUS-4-200/1 in lateral (K x 5) and aboral (L x 7) views, Kowala G, Detrital Beds, .Late Frasnian.



Górno A, Laskowa Gora Beds, Late Givetian: x 10. ❑K. *Floricrinus* sp.: columnal GIUS-4-198/1, Kowala E, Detrital Beds, Frasnian; x 10. ❑L. Pentagonostipes *petaloides* Morre & Jeffords 1968; columnal GIUS-4-90/201, Skały, Eifelian-Givetian passage Skały Beds; x 10.

Member (Gora Lgawa B, Jaźwica B). The species has been reported from the Givetian of Russia (Safonov horizon of the Kuznieck Basin; Dubatolova 1964).

Kasachstanocrinus acutilobus Dubatolova 1975 (Fig. 8A–B).— The colurnnals are pentagonal with strongly marked angles. The areola is also pentagonal, bordered by straight and thick culmina, longer in radial zones. Occurs in the Eifelian-Givetian passage Skaly Beds (Skaly) and probably also the Eifelian 'Dabrowa Limestone' (Grzegorzowice), Givetian Laskowa Gora Beds (Laskowa Gora A), Szydlowek Beds (Czarnów B), *Stringocephalus* Beds (Jurkowice-Budy A, Ołowianka B), Crinoid-Coral Level (Zbrza B), and Jaźwica Member (Poslowice B, Marzysz B, Gora Soltysia B, Stokowka B, Gora Lgawa B, Jaźwica B, Gora Zamkowa A2, Łagów B). Also the Givetian Dziewki Limestones (Siewierz BC). The species was firstly described from the Givetian of Russia (Beisk horizon of the Minusinsk Basin; Dubatolova 1975).

Kasachstanocrinus tenuis sp. **n.** (Fig. 8C–D; for description see p. 33).— The species occurs in the Givetian-Frasnian *Stingocephalus* Beds (Jurkowice-Budy A), Crinoid-Coral Level (Sowie Gorki C, Zbrza B), Jaźwica Member (Poslowice B, Gora Sołtysia B, Gora Lgawa B, Jaźwica B, Gora Zamkowa A2), and Lower Sitkowka Beds (Bilcza D); also the Givetian Dziewki Limestones (Siewierz BC).

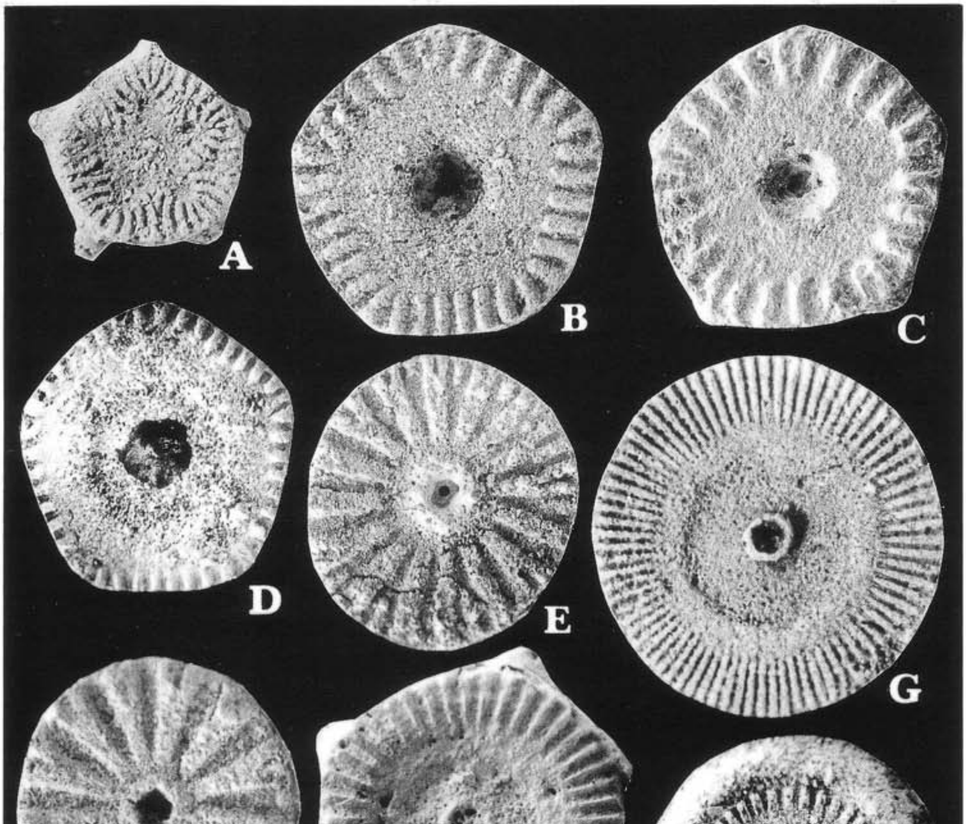
Family 'Kuzbassocrinidae' Stukalina 1975

***Gurjevskocrinus* punctulatus Dubatolova 1971** (Fig. 10H–I)— The columnals are barrel-like with delicate tubercles on lateral sides. The weakly marked decagonal areola is surrounded by straight culmina. Lumen is small and pentagonal. Occurs in the Eifelian-Givetian passage Skaly Beds (Skaly), probably also the Eifelian 'Dabrowa Limestone' (Grzegorzowice) and Givetian *Stringocephalus* Beds (Jurkowice-Budy *A).* The species was originally established in the latest Early Devonian of Russia (Malobatschat horizon of the Kuznieck Basin) (Dubatolova 1971).

Family 'Pentagonornischidae' Le Menn 1988

***Ricebocrinus* kulagaiensis (Dubatolova 1975)** (Fig. 9D).— The columnals are pentagonal, rounded with a smooth lateral side. Articular facet is bordered by very short and uniform culmina. Occurs in the Eifelian

Fig. 9. ❑A. *Facetocrinus quinqueangularis* (Dubatolova 1964); columnal GIUS-4-318/112, Laskowa Gora A, Laskowa Gora Beds, Givetian; x 7. ❑B, C. Ricebocrinus *parvus* sp. n.; holotype columnals GIUS-4-139/12 (B) and GIUS-4-139/13 (C), Góra Sołtysia B, Jaźwica Member, Late Givetian; x 20. ❑D. Ricebocrinus kulagaiensis (Dubatolova 1975); columnal GIUS-4-112/1, Łagów B, *Tenticospirifer* Level, Late Givetian; x 20. ❑E. F. Laudonomphalus pinguicostatus sp. n.; columnals GIUS-4-114/3 (E) and holotype GIUS-4-114/2 (F), Siewierz BC, Dziewki Limestones, Givetian; x 30. G. Laudonomphalus *humilicarinatus* (Yeltyschewa 1961); columnal GIUS-4-318/113, Laskowa Gora A, Laskowa Gora Beds, Givetian; x 5. ❑H. Laudonomphalus *torulosus* (Dubatolova 1971); columnal GIUS-4-99/2, Wietrmia A, Lower Wietrznia Beds, Late Givetian; x 5. ❑I. Laudonomphalus *mamillatus* (Yeltyschewa & Dubatolova 1960); columnal GIUS-4-99/1, Wietrznia A, Lower Wietrznia Beds, Late Givetian; x 7. ❑J. *Marettocrinus* angustannulus (Dubatolova 1975); columnal GIUS-4-114/1, Siewierz BC,



Dziewki Limestones, Givetian; × 10. ❑K–L. *Marettocrinus kartzevae* (Yeltyschewa & Dubatolova 1961); stem fragments GIUS-4-318/3 (K × 5) and GIUS-4-318/4 (L × 3), Laskowa Góra A, Laskowa Góra Beds, Givetian.

'Dąbrowa Limestone' (Grzegorzowice), Eifelian-Givetian passage Skaly Beds (Skaly), Givetian Świętomarz Beds (Świętomarz), Laskowa Gora Beds (Laskowa Gora A, Gorno A), Szydłówek Beds (Czarnów B), Lower Wietrznia Beds (Wietrznia A), Givetian *Stringocephalus* Beds (Jurkowice-Budy A), Crinoid-Coral Level (Sowie Górki C, Zbrza B), Jaźwica Member (Poslowice B, Marzysz B, Gora Sołtysia B, Stokowka B, Gora Łgawa B, Jaźwica B, Gora Zamkowa A2), *Tenticospirifer* Level (Łagów B), Lower Sitkowka Beds (Sitkowka-Kostrzewa BC, Bilcza D), Checiny Beds (Gora Zamkowa C–F, Sosnowka A, Zegzelogora AB), Frasnian Detrital Beds (Gora Zamkowa J). Also the Givetian Dziewki Limestones (Siewierz BC) and the Middle Devonian of Miastko-1 borehole in Pomerania. The species was firstly described from the Eifelian of Russia (Tatschip horizon of the Minusinsk Basin; Dubatolova 1975).

Ricebocrinus parvus sp. n. (Fig. 9B–C; for description see p. 34).— The species occurs in the Givetian-Frasnian Crinoid-Coral Level (Sowie Górki C, Zbrza B), Jaźwica Member (Poslowice B, Gora Sołtysia B, Jaźwica B, Gora Zamkowa A2), Lower Sitkowka Beds (Jaźwica F), Chęciny Beds (Gora Zamkowa C-F, Sosnowka A, Zegzelogora AB), and Frasnian, Detrital Beds (Gora Zarnkowa J); also the Givetian Dziewki Limestones (Siewierz BC).

Family 'Pentacauliscidae' Moore & Jeffords 1968

***Pentagonostipes* petaloides Moore & Jeffords 1968** (Fig. 8L).— The columnals are pentagonal with a smooth and slightly convex lateral side. Stellate areola is surrounded by numerous thin culmina. Lumen is pentagonal, strongly rounded and mostly small. Occurs in the Eifelian-Givetian passage Skaly Beds (Skaly).The species was first described from the Erian (Ludlowville Formation) of New York (Moore & Jeffords 1968).

Family 'Mediocrinidae' Stukalina 1964

***Mediocrinus microgrumosus* Dubatolova 1971** (Fig. 12F–G).— Stems are heteromorphic with tubercles on their lateral side. The articular facet of columnals is flat with wide, pentalobate, strongly rounded lumen. Crenularium is composed of numerous straight culmina. Occurs in the Eifelian 'Dqbrowa Limestone' (Grzegorzowice), and the Eifelian-Givetian passage Skaly Beds (Skaly). The species is known from the Eifelian of Russia (Mamontovo horizon of the Kuznieck Basin, Schivertinsk horizon of Altai; Dubatolova 1971).

Family 'Flucticharacidae' Moore & Jeffords 1968

Laudonomphalus humilicarinatus (Yeltyschewa 1961) (Fig. 9G).— Stems are heteromorphic with asymmetric keel on lateral side of columnals. Articular facet is bordered by straight, medium to long culrnina. Occurs in the latest Emsian Zagorze and Bukowa Gora Formations (Klonów Chain), Eifelian 'Dqbrowa Limestones' (Grzegorzowice, Bardo), Eifelian-Givetian passage Skaly Beds (Skaly), Givetian Laskowa Gora Beds (Laskowa Gora A), Givetian-Frasnian Lower Wietrznia Beds (Wietrznia A-B, Gorno C), *Stringocephalus* Beds (Jurkowice-Budy E), Upper Sitkowka Beds (Sowie Gorki G, Sitkowka-Kowala B, Jaźwica HI), Kadzielnia Member

(Kadzielnia A, Gora Cmentarna B), Phlogoiderhynchus Level (Wietrznia C, Dębska Wola G), Detrital Beds (Kadzielnia B, Kowala E, Gora Zamkowa J). Also Givetian Dziewki Limestones (Siewierz BC) and Early Frasnian of the Sudetes (Pogorzała-Witoszów section). The species is widely distributed in the Early-Middle Devonian of Russia (Salair to Safonovo horizons of the Kuznieck Basin; Kireev to Schivertinsk horizons of Altai; Favosites and *Conchidiella* Zones of the Urals; Hobotschalin horizon of Eastern Siberia; Valner horizon of Novaya Zemla) and in the Middle Devonian of Armenia (Dubatolova & Yeltyschewa 1961; Dubatolova 1971; Yeltyschewa & Stukalina 1977).

Laudonomphalus torulosus **(Dubatolova 1971)** (Fig. 9H).— The columnals are characterized by six large tubercles regularly arranged on their lateral sides. Articular facet is bordered by straight and rather thick culmina. Occurs in Late Givetian Lower Wietrznia Beds (Wietrznia A). The species was first described from the Eifelian(?) of Russia (Kireev horizon of Altai; Dubatolova 1971).

Laudonomphalus mamillatus **(Yeltyschewa & Dubatolova 1960)** (Fig. 9I).— The columnals with smooth, convex lateral sides. The articular facet is bordered by straight and thick culmina. Occurs in the Late Givetian Laskowa Gora Beds (Gorno A) and Lower Wietrznia Beds (Wietrznia A). Also in the Givetian Dziewki Limestones (Siewierz BC). This species has been reported from the Eifelian and Givetian of Siberia (Imatschi and Oldoi horizons of the Amur and Zeya Rivers Basin; Dubatolova 1971).

Laudonomphalus pinguicostatus sp. ***n.*** (Fig. 9E–F; for description see p. 34).— The species occurs in the Givetian Dziewki Limestones (Siewierz BC).

Marettocrinus kartzevae **(Yeltyschewa & Dubatolova 1961)** (Fig. 9K–L).— Stems are heteromorphic with strongly developed tubercles and irregular outhgrowths on the lateral sides of the columnals. The articular facet is bordered by straight and short to medium culmina. Occurs in the Eifelian-Givetian passage Skały Beds (Skały), Givetian Laskowa Gora Beds (Laskowa Gora A), Givetian-Frasnian Lower Wietrznia Beds (Wietrznia A-B, Gorno C), and Early Frasnian Phlogoiderhynchus Level (Wietrznia C); also the Early Frasnian of the Sudetes (Pogorzała-Witoszów section). The species is known from the Givetian-Frasnian of Russia (Beisk to Vassin horizons of the Kuznieck Basin, the Urals, and Novaya Zemla), Kazakhstan and Armenia (Dubatolova & Yeltyschewa 1961; Dubatolova 1971; Yeltyschewa & Stukalina 1977). Moreover, it occurs in the Givetian (Kerbelec and Lanvoy Formations) of the Armorican Massif, France (Le Menn 1985).

Marettocrinus angustannulus **(Dubatolova 1975)** (Fig. 9J).— Stems are heteromorphic with wide and smooth columnal epifacets. The articular facet is bordered by straight and short culmina. Occurs in the Eifelian-Givetian passage Skaly Beds (Skaly). Also Givetian Dziewki Limestone (Siewierz BC). The species has been reported from the Givetian of Russia (Beisk horizon of the Minusinsk Basin; Dubatolova 1975) and from the

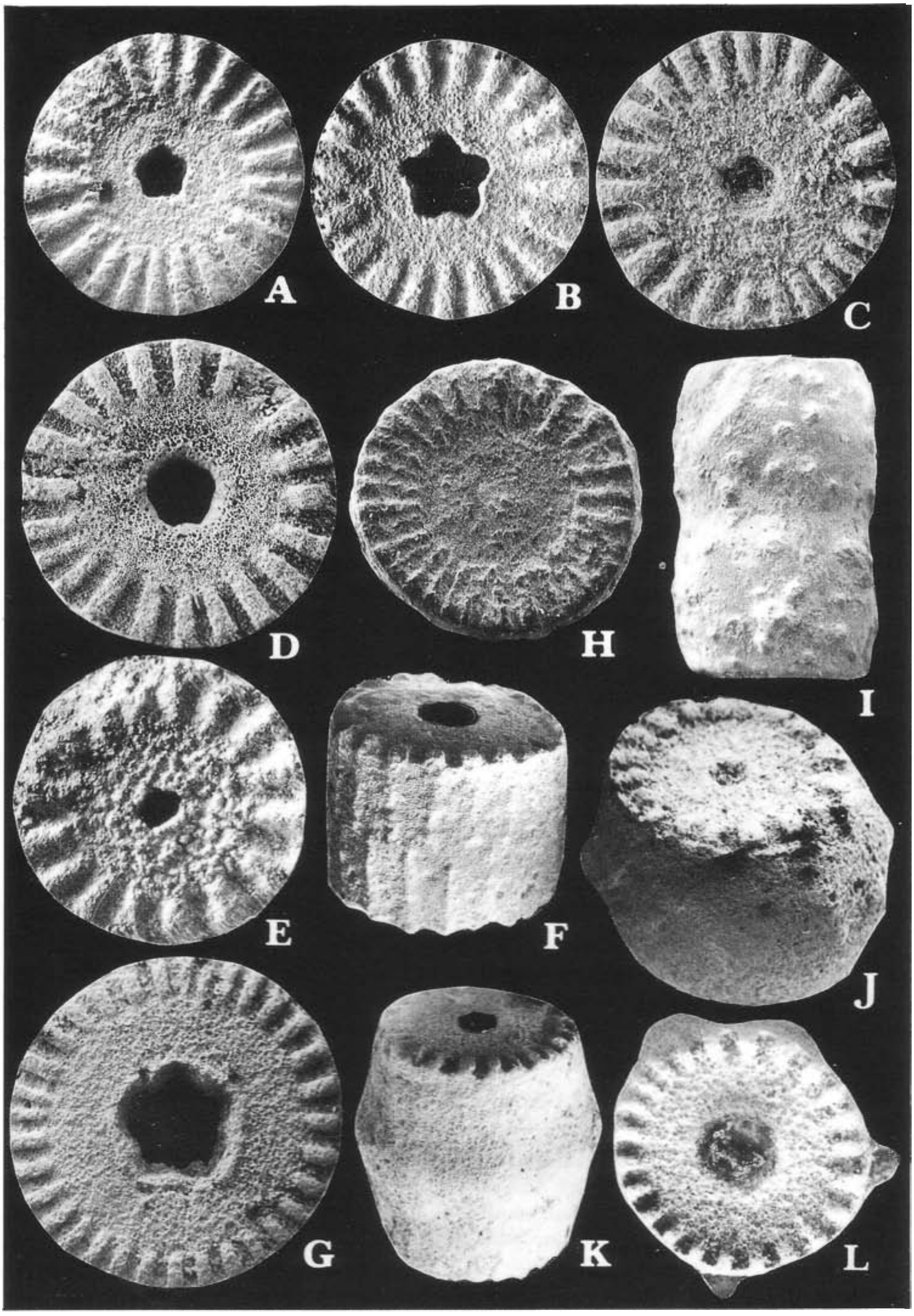
Late Eifelian (Quelern and Kersadiou Formations) of the Armorican Massif, France (Le Menn 1985).

Family 'Schyschcatocrinidae' Dubatolova 1971

Schyschcatocrinus creber Dubatolova 1975 (Fig. 10A–B).— Lateral sides of the colurnnals are smooth and convex to almost straight. Articular facet is bordered by straight and thick culmina. Lumen is pentalobate, surrounded by a flat areola. Occurs in the Eifelian-Givetian passage Skały Beds (Skały), Givetian Świętomarz Beds (Świętomarz), Laskowa Gora Beds (Laskowa Gora A, Gorno A), Lower Wietrznia Beds (Wietrznia A), the Stringocephalus Beds (Olowianka B, Jurkowice-Budy E), Crinoid-Coral Level (Sowie Górki C), and Jaźwica Member (Poslowice B, Marzysz B, Gora Zarnkowa A2). Also Givetian Dziewki Limestone (Siewierz BC), Debnik Limestone (Debnik A), and the Middle Devonian of Pomerania (Miastko-1 borehole). According to the currently accepted concept of S. creber, most of minute specimens previously included in it have been transfered to other species. Its reports from the Late Devonian (Gluchowski 1981a, b) should be thus abandoned. This species was initially reported from the Givetian of Russia (Beisk horizon of the Minusinsk Basin; Dubatolova 1975).

Schyschcatocrinus delicatus sp. n. (Fig. 10C–D; for description see p. 36).— The species occurs in the Givetian Laskowa Gora Beds (Laskowa Gora A, Gomo A), Givetian-Frasnian Szydlowek Beds (Czarnów B, Szydłówek A, Wola Jachowa), Lower Wietrznia Beds (Wietrznia A–B, Gorno C), Stringocephalus Beds (Olowianka B), Crinoid-Coral Level (Sowie Górki C, Zbrza B), Jaźwica Member (Poslowice B, Marzysz B, Gora Soltysia B, Stokowka B, Gora Lgawa B, Jaźwica B, Gora Zarnkowa A2), Sitkowka Beds (Sitkowka-Kostrzewa BC, Bilcza D, Jaźwica F–HI, Sowie Górki G, Sitkówka-Kowala B), *Tenticospirifer* Level (Łagów B), Kadzielnia Member (Kadzielnia A, Gora Cmentarna B, Kowala C, Gora Lgawa J), Chęciny Beds (Gora Zamkowa C–F, Sosnówka A, Zegzelogora AB), Phlogoiderhynchus Level (Wietrznia C, Kowala D, Dębska Wola G), Detrital Beds (Kadzielnia B, Szczukowskie Górki, Grabina BC, Psie Gorki G, Sitkówka-Jaźwica BC, Miedzianka E, Kowala E–H, Gora Zamkowa J, Tudorow), Marly Beds (Sobiekurow), Kostomloty Beds (Domaszowice, Kostomloty F–H), and *Manticoceras* Limestone (Daleszyce); also the Dziewki Limestone (Siewierz BC), Debnik Limestone (Debnik A), and Grained Limestone (Debnik D).

Fig. 10. □A–B. Schyschcatocrinus creber Dubatolova 1975: columnals GIUS-4-107/41-42, Gorno A, Laskowa Góra Beds, Late Givetian: x 10. □C, D. Schyschcatocrinus delicatus sp. n.; holotype columnals GIUS-4-146/1 (C), Gora Zamkowa C, Chęciny Beds, and GIUS-4-196/8 (D), Gorno A, Laskowa Gora Beds, Late Givetian; x 30. □E. Schyschcatocrinus sp. A; columnal GIUS-4-99/3, Wietrznia A, Lower Wietrznia Beds, Late Givetian; x 10. □F. Schyschcatocrinus sp. B; columnal GIUS-4-196/2, Górno A, Laskowa Gora Beds, Late Givetian; x 10. □G. Amurocrinus *imatschensis* (Yeltyschewa & Dubatolova 1961); columnal GIUS-4-100/1, Świętomarz, Świętomarz Beds, Early Givetian; x 10. □H–I. *Gurjevskocrinus punctulatus* Dubatolova 1971; columnals GIUS-4-90/208 (H x 20) and GIUS-4-90/209 (I x 15), Skały, Eifelian-Givetian



passage Skały Beds. ❑J–L. *Schyschcatocrinus multiformis* sp. *n.*; holotype columnals GIUS-4-196/23 (J) and GIUS-4-196/24-25 (K–L), Gomo A, Laskowa Gora Beds, Late Givetian; x 10.

***Schyschcatocrinus multiformis* sp. n.** (Fig. 10J–L; for description see p. 36).—The species occurs in the Givetian Laskowa Gora Beds (Gorno A), Givetian-Frasnian Szydlowek Beds (Szydlowek A, Czarnów B, Wola Jachowa), Lower Wietrznia Beds (Wietrznia A–B, Gorno C); Early Frasnian *Phlogoiderhychus* Level (Wietrznia C, Kowala D), Kadzielnia Member (Kadzielnia A, Gora Cmentarna B, Gora Łgawa J, Kowala C), Upper Sitkowka Beds (Sowie Gorki G, Sitkowka-Kowala B, Jaźwica HI), Detrital Beds (Kadzielnia B, Szczukowskie Gorki, Kowala E).

Schyschcatocrinus* sp. *A (Fig. 10E).— The outline and size of these columnals are similar to those of *S. creber.* However, despite poor preservation, they are distinct in having a peculiar areola covered with marked tubercles. Occurs in the Givetian Laskowa Gora Beds (Gorno A), Lower Wietrznia Beds (Wietrznia A); also the Givetian Dziewki Limestone (Siewierz BC) and Debnik Limestone (Dębnik A).

***Schyschcatocrinus* sp.** B (Fig. 10F).— These poorly preserved columnals generally resemble those of *S. multiformis* but can be distinguished by lateral ornamentation of the columnals which consists of vertical ridges arranged alternately in the lower and upper part. Occurs in the Givetian Laskowa Gora Beds (Gorno A).

***Amurocrinus imatschensis* (Yeltyschewa & Dubatolova 1961)** (Fig. 10G).— Lateral sides of the columnals are straight or slightly convex, smooth or with minute tubercles. The articular facet is bordered by a narrow crenularium. The lumen is pentalobate, wide and surrounded by perilumen. Occurs in the Givetian Świętomarz Beds (Świętomarz), Laskowa Gora Beds (Laskowa Gora A, Gorno A), Szydlowek Beds (Szydlowek A), and Lower Wietrznia Beds (Wietrznia A). The species has been reported from the Early-Middle Devonian of Russia (Bolsheneversk to Imatschi, and Oldoi? horizons of the Amur River Basin, Kuvash and Belgebasch horizons of Altai; Dubatolova & Yeltyschewa 1961; Dubatolova 1971).

Family 'Stenocrinidae' Dubatolova 1971

***Stenocrinus degratus* Dubatolova 1975** (Fig. 11B–C).— The lumen of these colurnnals is pentagonal, strongly rounded. Crenularium consists of straight or rarely dichotomous culmina. Lateral sides of the columnals are smooth. Occurs in the Eifelian-Givetian passage Skaly Beds (Skaly), Givetian Świętomarz Beds (Świętomarz), Laskowa Gora Beds (Laskowa

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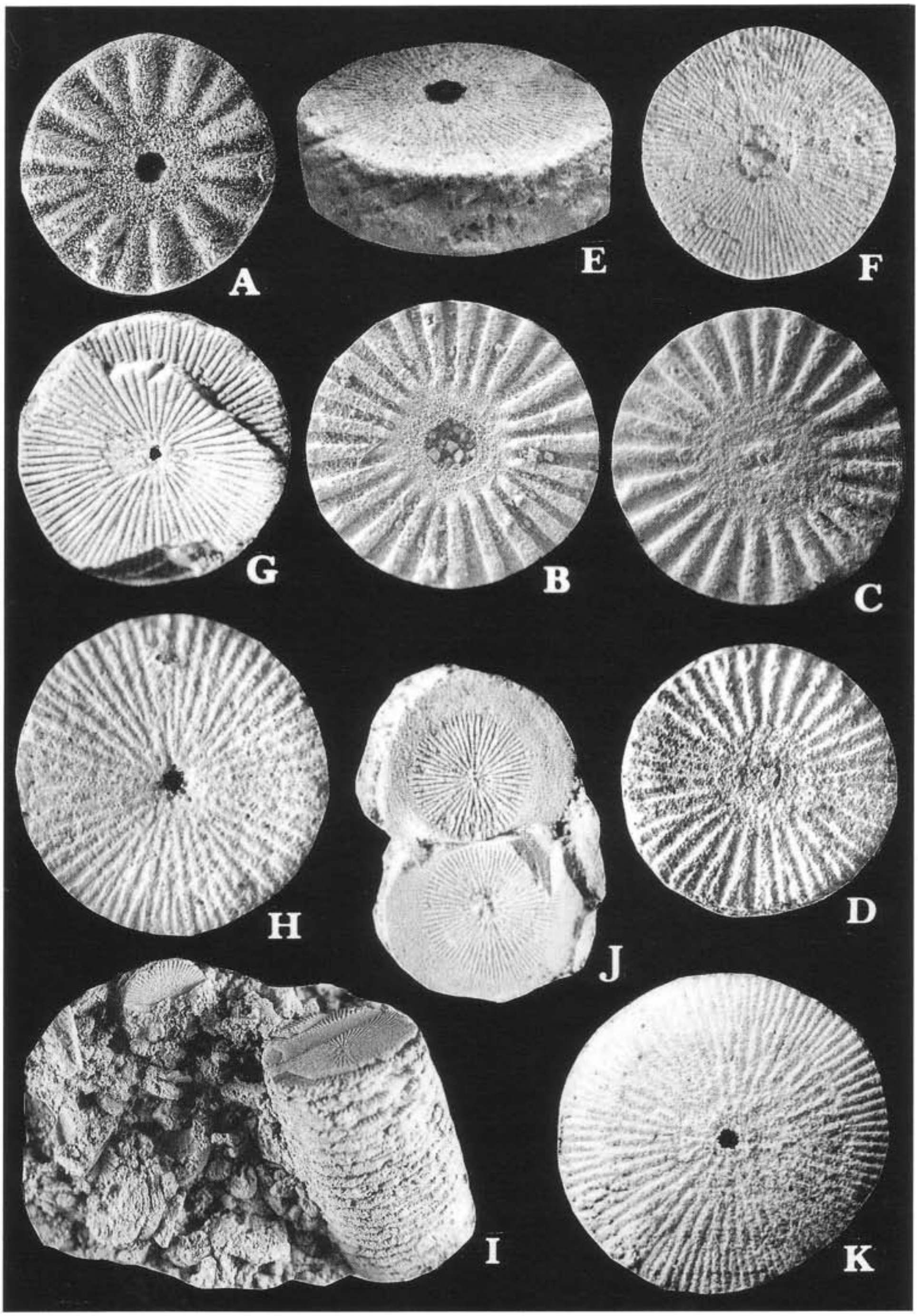
Fig. 11. ❑A. Stenocrinus *raricostatus* sp. n.; holotype colurnnal GIUS-4-126/10, Jurkowice-Budy A, Stringocephalus Beds, Early Givetian; x 30. ❑B–C. Stenocrinus degratus Dubatolova 1975; columnals GIUS-4-98/3 (B), Jurkowice-Budy E, Stringocephalus Beds, Givetian; x 20 and GIUS-4-107/3 (C), Gorno A, Laskowa Gora Beds, Late Givetian; x 15. ❑D. Stenocrinus *cf. bifurcatus* Dubatolova 1971: columnal GIUS-4-318/121, Laskowa Gora A, Laskowa Gora Beds, Givetian: x 10. ❑E. *Salairocrinus* sp.; columnal GIUS-4-318/122, Laskowa Gora A, Laskowa Beds Beds, Givetian; x 7. ❑F. *Salairocrinus* humilis (Dubatolova) 1964; columnal GIUS-4-90/27, Skaly, Eifelian-givetian passage Skały Beds; x 5. ❑G–I. Calleocrinus *kielcensis* sp. n.; stem fragments GIUS-4-10/10 (G x 4), Sitkówka-Jaźwica BC, Detrital Beds, Late Frasnian; holotype GIUS-4-200/10 (H), Kowala G, Detrital Beds, Late Frasnian; x 9 and GIUS-4-103/1 (I x 3), Panek B, Detrital Beds, Late Frasnian. ❑J–K. Calleocrinus *bicostatus*



sp. n.; stem fragments GIUS-4-10/11 (J × 3), Sitkówka-Jaźwica BC, Detrital Beds, Late Frasnian, and holotype GIUS-4-93/1 (K x 7.5), Kadzielnia A, Kadzielnia Member, Early Frasnian.

Gora A, Gorno A), Lower Wietrznia Beds (Wietrznia A), *Stringocephalus* Beds (Olowianka B, Jurkowice-Budy E), Crinoid-Coral Level (Sowie Górki C), and Jaźwica Member (Poslowice B, Marzysz B, Gora Zarnkowa A2). Also the Givetian Dziewki (Siewierz BC) and Debnik Limestones (Debnik A). As the range of *S. degratus* has been narroved, its presence in the Late Devonian (Gluchowski 1981a, b) is no longer proposed. The species was originally described from the Late Eifelian of Russia (Tatschip horizon of the Minusinsk Basin; Dubatolova 1975).

Stenocrinus raricostatus* sp. *n. (Fig. 11A; for desctription see p. 37).— The species occurs in the Givetian Laskowa Gora Beds (Laskowa Gora A, Gorno A), Givetian-Frasnian Szydlowek Beds (Szydłówek A, Czarnow B, Wola Jachowa), Lower Wietrznia Beds (Wietrznia A–B, Gorno C), *Stringocephalus* Beds (Olowianka B, Jurkowice A–E), Crinoid-Coral Level (Sowie Górki C, Zbrza B), Jaźwica Member (Posłowice B, Marzysz B, Gora Soltysia B, Stokowka B, Gora Lgawa B, Jaźwica B, Gora Zamkowa A2), *Tenticospirifer* Level (Łagów B), Kadzielnia Member (Kadzielnia A, Gora Cmentarna B, Kowala C, Gora Lgawa J), Chęciny Beds (Gora Zamkowa C–F, Sosnowka A, Zegzelogóra AR), Sitkowka Beds (Sitkowka-Kostrzewa BC, Bilcza D, Sitkowka-Kowala B, Sowie Gorki G, Jaźwica F–HI), Early Frasnian *Phlogoiderhynchus* Level (Wietrznia C, Kowala D, Debska Wola G), and Detrital Beds (Gora Zarnkowa J, Szczukowskie Górki, Kadzielnia B). Also the Givetian Dziewki (Siewierz BC) and Dębnik Limestones (Debnik A), and the Frasnian of the Sudetes (Pogorzała-Witoszów section).

***Stenocrinus cf. bifurcatus* Dubatolova 1971** (Fig. 11D).— Articular facet shows general similarity to S. *bifurcatus* but Polish columnals differ from the Russian specimens in less frequent bifurcation of the culmina. Occurs in the Eifelian-Givetian passage Skały Beds (Skały) and Givetian Laskowa Gora Beds (Laskowa Gora A). S. *bifurcatus* occurs in the Eifelian of Russia (Marnontovo horizon of the Kuznieck Basin; *Conchidiella* Zone of the Urals; Dubatolova 1971; Milicina 1977).

Calleocrinus kielcensis* sp. *n. (Fig. 11G–I; for description see p. 38).— The species occurs in the Frasnian Lower Wietrznia Beds (Gorno C), *Phlogoiderhynchus* Level (Wietrznia C, Dębska Wola G), Kadzielnia Member (Kadzielnia A, Gora Cmentarna B), Upper Sitkowka Beds (Sowie Górki G, Jaźwica HI), Detrital Beds (Góra Zamkowa J, Kadzielnia B, Szczukowskie Górki, Grabina BC, Kowala E-H, Sitkówka-Jaźwica BC, Panek B, Miedzianka E, Kostomloty F-H), and Frasnian Grained Limestone (Debnik D). This species occur probably also in the Frasnian (Frasnes and Neuville Formations) of the Dinant Basin, Belgium.

Calleocrinus bicostatus* sp. *n. (Fig. 11J–K; for description see p. 39).— The species occurs in the Frasnian Kadzielnia Member (Kadzielnia A) and Detrital Beds (Kadzielnia B, Sitkówka-Jaźwica BC, Panek B) of the Kowala Formation.

***Glyphidocrinus infimus* (Dubatolova 1964)** (Fig. 12I–J).— Stems are heteromorphic with well-developed smooth epifacets. Articular facet of the columnals is slightly concave at its margin and bordered by short and thick culmina. Occurs in the Frasnian Lower Wietrznia Beds (Gorno C), *Phlogoiderhynchus* Level (Wietrznia C, Dębska Wola G), Upper Sitkowka Beds (Sowie Górki G), Kostomloty Beds (Kostomloty F–H), Detrital Beds (Szczukowskie Górki, Kowala E, Psie Górki G, Sitkówka-Jaźwica BC, Tudorow), and Frasnian Grained Limestone (Dębnik D). The species is known from the Frasnian of Russia (Kurlyak horizon of the Kuznieck Basin; Dubatolova 1964).

Glyphidocrinus sp. (Fig. 12H).—These poorly preserved columnals are generally similar to those of G. *infimus* but differ in strongly narrowed crenularium, finer culmina and more concave margin of the articular facet. Occurs in the Eifelian-Givetian passage Skaly Beds (Skaly), Givetian Laskowa Gora Beds (Laskowa Gora A, Gorno A), Szydlowek Beds (Szydłówek A), *Stringocephalus* Beds (Ołowianka B, Jurkowice-Budy E), and Givetian-Frasnian Lower Wietrznia Beds (Wietrznia B). Also the Givetian Dziewki Limestone (Siewierz BC).

Family 'Salairocrinidae' Dubatolova 1971

Salairocrinus humilis **(Dubatolova 1964)** (Fig. 11F).— The columnals are low with smooth lateral sides. The articular facet is flat with pentalobate, rounded lumen and numerous and dichotomous culmina. Occurs in the Eifelian 'Dabrowa Limestone' (Grzegorzowice section) and Eifelian-Givetian passage Skaly Beds (Skały). The stratigraphic range of the species is restricted to the Eifelian. Reports from Givetian-Frasnian localities (Głuchowski 1981a, b) were incorrect. The species is known from the Emsian-Eifelian of Russia (Salair horizon of the Kuznieck Basin, Kireev horizon of Altai, *Conchidiella* Zone of the Urals; Dubatolova 1964, 1971).

Salairocrinus sp. (Fig. 11E).— Poorly preserved columnal material may comprise more than one species. The specimens differ in the size of the articular facet and lumen. A significantly larger columnal height index (KHi>10) excludes them from S. *humilis*. Occurs in the Givetian Świętomarz Beds (Świętomarz), Laskowa Góra Beds (Laskowa Gora A, Gorno A), Givetian-Frasnian Lower Wietrznia Beds (Wietrznia B, Gorno C), Frasnian *Phlogoiderhynchus* Level (Wietrznia *C*). and Kadzielnia Member (Kadzielnia A, Gora Cmentarna B).

Tjeecrinus simplex **(Yeltyschewa 1955)** (Fig. 12A–B).— Lateral sides of the columnals are smooth and slightly convex. The articular facet is flat, covered with straight and thick culmina nearly reaching the stellate lumen. Occurs in the Givetian Laskowa Gora Beds (Gorno A), Givetian-Frasnian Szydlowek Beds (Szydłówek A, Czarnów B, Wola Jachowa), Lower Wietrznia Beds (Wietrznia A-B, Gomo C), *Phlogoiderhynchus* Level (Wietrznia C, Kowala D), Crinoid-Coral Level (Sowie Górki C), Jaźwica Member (Poslowice B, Marzysz B, Gora Zamkowa A2), *Tenticospirifer* Level (Łagów B), Sitkowka Beds (Sitkowka-Kostrzewa BC, Jaźwica F–HI), Chęciny Beds (Zegzelogóra AB), and Kadzielnia Member (Kadzielnia A, Gora Cmentarna B, Kowala C); also the Late Givetian Dębnik Limestone (Dębnik A) and the Frasnian of the Sudetes (Pogorzala-Witoszow section). The species is known from the Givetian of Russia (Beiskhorizon of the Minusinsk Basin; Yeltyschewa 1955; Dubatolova 1975).

Tjeecrinus crassijugatus **Dubatolova 1975** (Fig. 12C).— Lateral sides of the columnals are smooth and slightly convex. The articular facet is covered with straight and dichotomous culmina reaching the small pentalobate lumen. Occurs in the Eifelian-Givetian passage Skaly Beds (Skaly), Givetian Świętomarz Beds (Świętomarz), Laskowa Gora Beds (Laskowa Gora A, Gorno A), and *Stringocephalus* Beds (Jurkowice-Budy E); also the Givetian Dziewki Limestone (Siewierz BC). The species has been reported from the Givetian of Russia (Beisk horizon of the Minusinsk Basin; Dubatolova 1975) and France (Blacourt Formation of Boulonnais; Le Menn 1988).

Tjeecrinus insectus **(Yeltyschewa in Dubatolova 1964)** (Fig. 12D–E).— Stems are homomorphic(?) with highly visible sutures between columnals. The articular facet is covered with medium thick, straight and dichotomous culmina. The lumen is small and pentalobate. Occurs in the Late Frasnian Kostomloty Beds (Kostomloty F–H, Domaszewice), *Manticoceras* Limestone (Daleszyce), Marly Limestone (Sobiekurow), and Detrital Beds (Psie Gorki G, Sitkówka-Jaźwica BC, Miedzianka E, Kowala H, Tudorow); also the Late Frasnian Grained Limestone (Dębnik D). The species occurs in the Frasnian of Russia (Kurlyak and Solomino horizons of the Kuznieck Basin; Dubatolova 1964) and probably also in the Frasnian of Belgium (Neuville Formation of the Dinant Basin).

Family 'Asperocrinidae' Stukalina 1975

Asperocrinus brevispinosus **sp. n.** (Fig. 12K; for description see p. 39).— The species occurs in Eifelian-Givetian passage Skaly Beds (Skaly) and probably also Eifelian 'Dąbrowa Limestone' (Grzegorzowice) and *Stringocephalus* Beds (Jurkowice-Budy A–E); also the Givetian Dziewki Limestone (Siewierz BC).

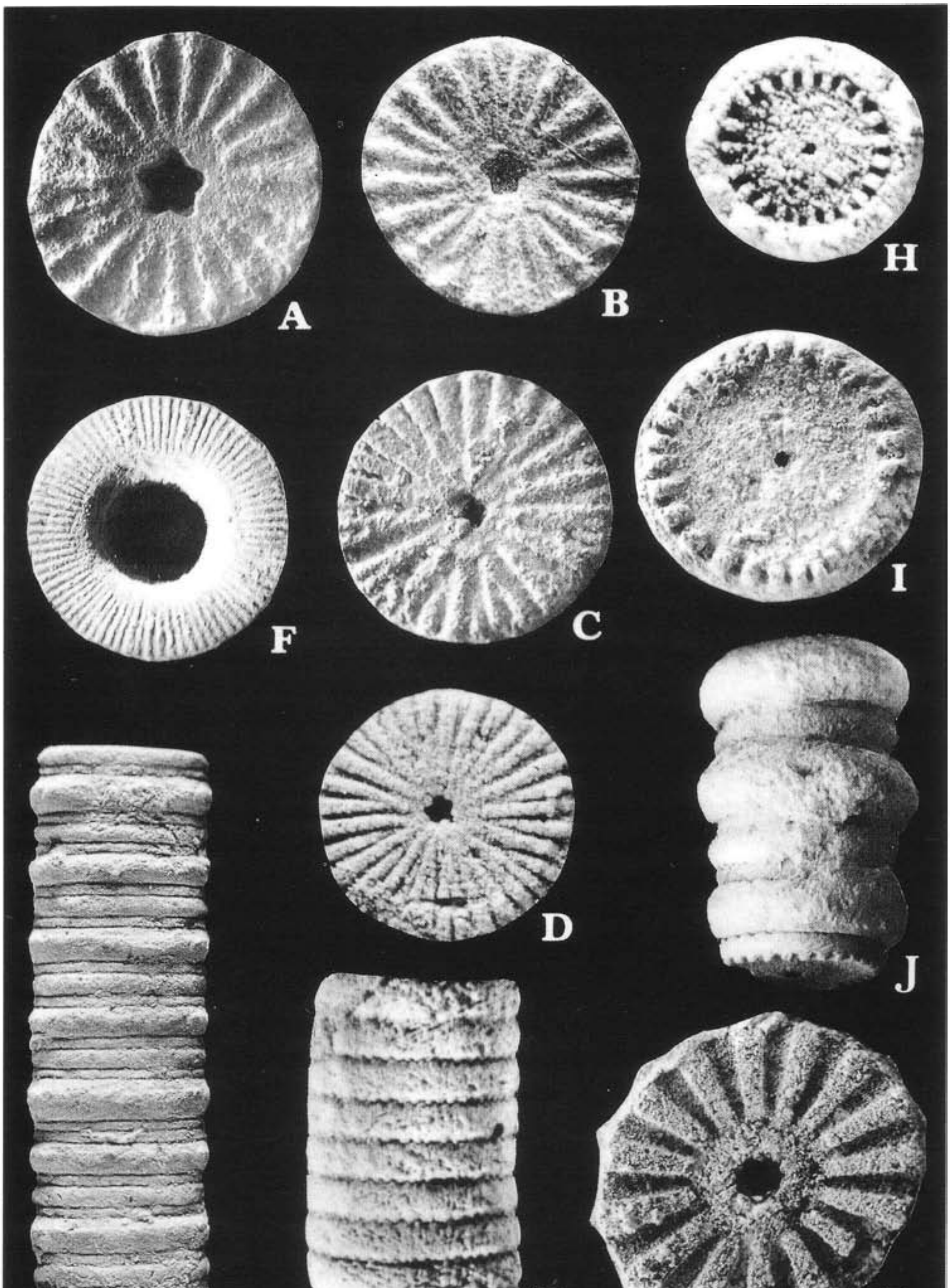
Family 'Exaesiodiscidae' Moore & Jeffords 1968

Exaesiodiscus compositus **sp. n.** (Fig. 13J–K; for description see p. 41).— The species occurs in the Late Frasnian Detrital Beds (Sitkowka-Jaźwica BC, Kowala G).

Family 'Kstutocrinidae' Schewtschenko 1966

Kstutocrinus **sp.** (Fig. 13L).— High columnals with minute pentagonal lumen, typical for the genus (see Schewtschenko 1966), show extensive variability in the columnal height index (KHi) and convexity of lateral sides, with transitions from strongly barrel-like to cylindrical shapes. Occurs in

Fig. 12. □A–B. Tjeecrinus simplex (Yeltyschewa 1955); columnals GIUS-4-107/4–5, Gorno A, Laskowa Gora Beds, Late Givetian; x 10. □C. Tjeecrinus *crassijugatus* Dubatolova 1975; columnal GIUS-4-98/6, Jurkowice-Budy E, Stringocephalus Beds, Givetian; x 10. □D–E. Tjeecrinus *insectus* (Yeltyschewa 1964); stem fragments GIUS-4-103/2–3, Panek B, Detrital Beds, Late Frasnian; x 10. □F–G. Mediocrinus *microgrumosus* Dubatolova 1971; stem fragments GIUS-4-90/21–22, Skaly, Eifelian-Givetian passage Skały Beds; x 7. □H. *Glyphi*docrinus sp.; columnal GIUS-4-98/5, Jurkowice-Budy E, Stringocephalus Beds, Givetian;



❑I–J. *Glyphidocrinus infimus* (Dubatolova 1964); stem fragment GIUS-4-208/1, Gomo C, Lower Wietrznia Beds, Early Frasnian (I x 8), (J x 5). OK. *Asperocrinus brevispinosus* sp. n.; holotype columnal GIUS-4-114/11, Siewierz BC, Dziewki Limestone, Givetian; x 30.

the Givetian Laskowa Gora Beds (Laskowa Gora A, Gorno A), Givetian-Frasnian Szydlowek Beds (SzydlowekA, Czarnów B, Wola Jachowa), Lower Wietrznia Beds (Wietrznia B, Gorno C), Crinoid-Coral Level (Zbrza B), Sitkowka Beds (Sowie Gorki G, Sitkowka-Kowala B), Kadzielnia Member (KadzielniaA, Gora Cmentarna B, Kowala C), Frasnian *Phlogoiderhynchus* Level (Wietrznia C, Kowala D), Kostomloty Beds (Kostomloty F–H, Domaszowice), Detrital Beds (Psie Gorki G, Tudorow), *Manticoceras* Limestone (Daleszyce), and Marly Beds (Sobiekurow); also the Frasnian Grained Limestone (Dębnik D).

Family 'Tantalocrinidae' Le Menn 1985

Tantalocrinus scutellus* Le Menn *1985 (Fig. 13F).— Stems are heteromorphic with straight or convex lateral sides usually covered with rows of tubercles at the mid-heigth of columnals. The lumen is very wide and circular. The crenularium is narrow and composed of numerous, dichotomous culmina. Occurs in the Eifelian-Givetian passage Skaly Beds (Skały) and Givetian Laskowa Gora Beds (Laskowa Gora A, Gorno A). The species was first described from the Givetian (Kerbelec and Lanvoy Formations) of the Armorican Massif, France (Le Menn 1985).

***Noctuicrinus? varius* sp. n.** (Fig. 13A–D; for description see p. 41).— The species occurs in the Givetian *Stringocephalus* Beds (Jurkowice-Budy A).

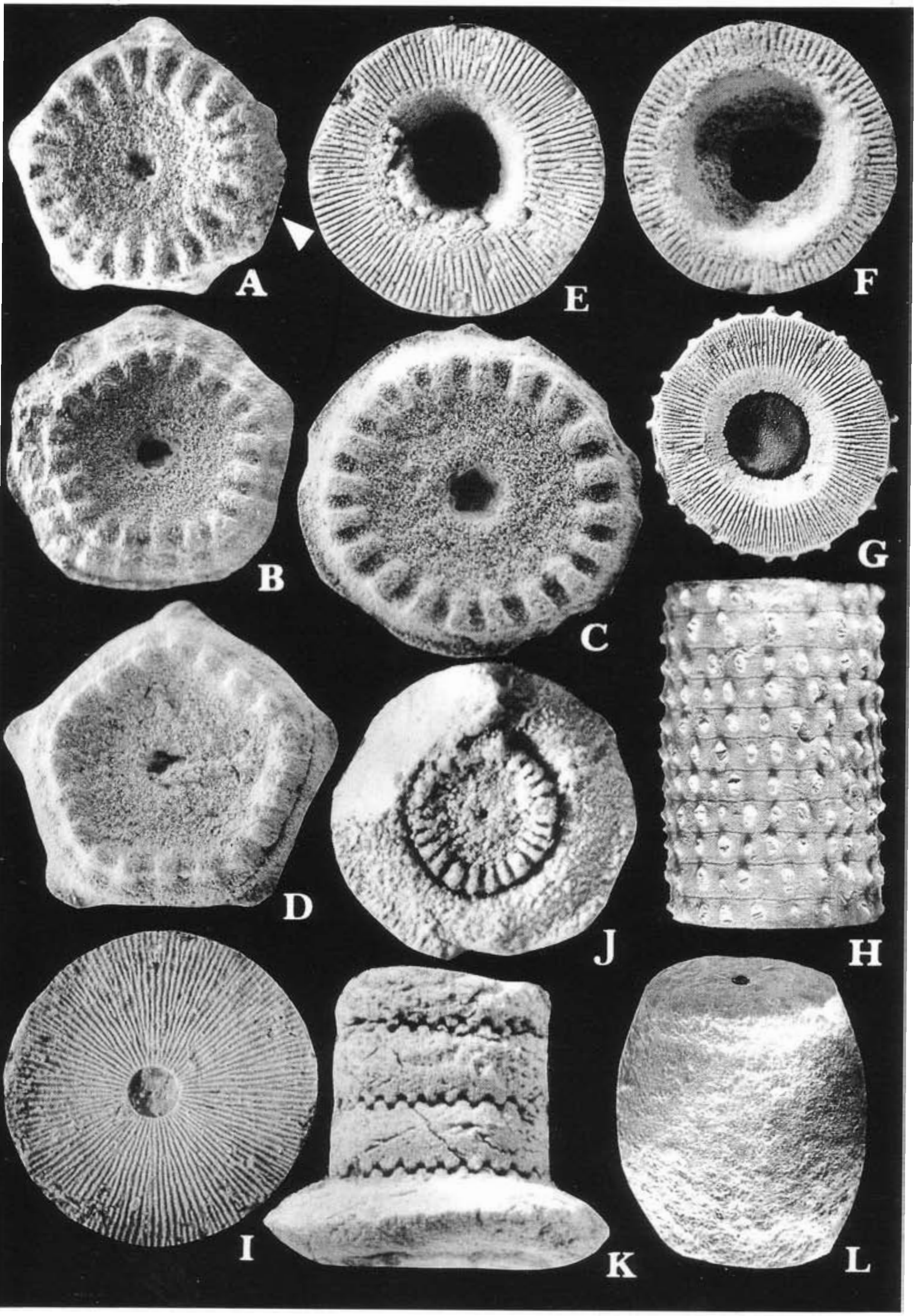
Family 'Peribolocrinidae' Dubatolova 1971

***Peribolocrinus* sp.** (Fig. 13E).— Luminal index (Li), and the columnal height are very variable in these poorly preserved specimens, which may represent more than one species. Occurs in the Eifelian-Givetian passage Skaly Beds (Skaly), Givetian Laskowa Gora Beds (Laskowa Gora A, Gorno A), Givetian-Frasnian Lower Wietrznia Beds (Wietrznia A–B, Gorno C), and Early Frasnian *Phlogoiderhynchus* Level (Wietrznia C).

***Cycloocetocrinus multigranulatus* (Yeltyschewa & Stukalina 1977)** (Fig. 13G–H).— Stems are homeomorphic, composed of low columnals with thorny tubercles on their lateral sides. The articular facet is flat or slight concave near the wide circular lumen. The crenularium is composed of very numerous and dichotomous culmina. Occurs in the Eifelian-Givetian passage Skaly Beds (Skaly). The species has been reported from the Eifelian of Novaya Zemla, Russia (Yeltyschewa & Stukalina 1977).

***Cycloocetocrinus* sp.** (Fig. 13I).— These columnals show variable lateral sculpture (nodes, spines), which remains generally less prominent than in C. *multigranulatus* in some specimens being completely missing.

Fig. 13. □A–D. Noctuicrinus? *varius* sp. n.; holotype columnals GIUS-4-126/1 (A) and GIUS-4-126/11–13 (B–D), Jurkowice-Budy A, *Stringocephalus* Beds, Early Givetian; × 30. □E. Peribolocrinus sp.; columnal GIUS-4-99/11, Wietrznia A, Lower Wietrznia Beds, Late Givetian; x 10. □F. Tantalocrinus scutellus Le Menn 1985; columnal GIUS-4-318/22, Laskowa Gora A, Laskowa Gora Beds, Givetian; x 7. □G–H. Cycloocetocrinus *multigranulatus* (Yeltyschewa & Stukalina 1977); stem fragment GIUS-4-90/200, Skaly, Eifelian-Givetian passage Skały Beds: x 8. □I. Cycloocetocrinus sp.; columnal GIUS-4-318/1, Laskowa Góra A, Laskowa Gora Beds, Givetian; x 6. □J–K. Exaesiodiscus compositus sp. n.; stem fragments GIUS-4-10/2;



(J×8) and holotype GIUS-4-10/1 (K x 10), Sitkówka-Jaźwica BC, Detrital Beds, Late Frasnian. OL. *Kstutocrinus* sp.; columnal GIUS-4-111/2, Szydlowek A, Szydlowek Beds, Late Givetian; x 15.

In this respect they are more similar to C. *rarigranulatus* (Yeltyschewa & Stukalina 1977). Occurs in the Eifelian-Givetian passage Skały Beds (Skały), Givetian Laskowa Gora Beds (LaskowaGora A, Gomo A),Givetian-Frasnian Lower Wietrznia Beds (Wietrznia A, B), and Early Frasnian *Phlogoiderhynchus* Level (WietrzniaC).

Descriptions of new species

Group Pentameri Moore & Jeffords 1968

Family 'Anthinocrinidae' Yeltyschewa & Sisova *in* Schewtschenko 1966

Genus *Anthinocrinus* Stukalina 1961

Type species: Anthinocrinus *ludlowicus* Stukalina 1961.

Anthinocrinus brevicostatus sp. *n.*

Fig. 8E.

Holotype: GIUS-4-107/15, Fig. 8E.

Type locality: Góra Józefka near Gbmo, set A, Holy Cross Mountains.

Type horizon: Laskowa Góra Beds; *K. disparilis* Zone.

Derivation of the name: From Latin brevis – short, costa – crenula.

Diagnosis. — Columnal articulum pentagonal in outline; lumen pentagonal; areola pentalobate, well-developed; culmina straight and short.

Material. — More than 100 columnals, two stem fragments.

Dimensions of the holotype (in mm).— Colurnnal diameter (KD) 2.3; facetal diameter (FD) 2.0; luminal diameter (LD)0.4; areolar diameter (AD) 1.2; crenularial diameter (CD)0.4; columnal height (KH) 0.6.

Description. — Heteromorphic stems are composed of low columnals of at least 4 orders. Columnals are pentagonal to stellate, with convex and smooth lateral side. Articular facet is of pentagonal, rounded outline with facetal shape index (FSi) 75 to 80. Areola is broad, pentalobate and surrounded by rather thick, very short culrnina range from 30 to 35 in number. Lumen is pentagonal, strongly rounded, and its size is more constant than areola one during ontogenetic growth (Fig. 14A).

Remarks. — The new species differs from closest A. *subisodentatus* (Dubatolova 1971) from the Early Devonian of Russia in the more rounded lobes of the areola, relatively smaller lumen and less numerous culmina. Similar Early Devonian A. *terminalis* (Schewtschenko 1966) and A. *sangulus* (Schewtschenko 1966) have longer culmina in the radial zone of columnal than the new species.

Occurrence. — See p. 16.

Genus *Urushicrinus* Stukalina & Schischikina 1979

Type species: Anthinocrinus *eugeniae* Yeltyschewa & Dubatolova 1967.

Urushicrinus perbellus sp. *n.*

Fig. 8H–I.

Holotype: GIUS-4-148/6, Fig. 8I.

Type locality: Sowie Gorki, set C, Holy Cross Mountains.

Type horizon: Crinoid-Coral Level [equivalent of the Jaźwica Member) at the base of the Sitkowka Beds, Kowala Formation; mostly earliest M. *falsiovalis* Zone.

Derivation of the name: From Latin perbellus – very nice.

Diagnosis. — Pentagonal articular facet of the columnals with broad areola, pentagonal lumen and incomplete crenularium.

Material.— Sixteen columnals.

Dimensions of the holotype (in mm).— Columnal diameter (KD) 1.8; facetal diameter (FD)1.7; luminal diameter (LD)0.2; areolar diameter (AD) 1.3; crenularial diameter (CD)0.2; columnal height (KH)0.4.

Description. — These heteromorphic stems show smooth and gently convex columnal lateral sides. Columnals are low, pentagonal to stellate in shape, with blunted angles. Lumen is large-sized, pentagonal, strongly rounded. Articular facet is flattened, pentagonal with facetal shape index (FSi) 80 to 90 and bordered by 3 (rarely 4) coarse and short culmina grouped peripherally, solely in the radial zones. This culmina pattern defines the characteristic shape of the areola. Lenght of the culmina is more constant than lumen size during ontogenetic growth (Fig. 14B).

Remarks. — The species displays distinctly shorter culmina than in the most similar U. *eugeniae* (Dubatolova *et al.* 1967) from the Early-Middle Devonian of Russia.

Occurrence. — See p. 16.

Genus *Kasachstanocrinus* Sisova *in* Schewtschenko 1966

Type species: Kasachstanocrinus *asperum* Schewtschenko 1966.

Kasachstanocrinus tenuis sp. *n.*

Fig. 8C, D.

Holotype: GIUS-4-126/3, Fig. 8D.

Type locality: Jurkowice-Budy, set A, Holy Cross Mountains.

Type horizon: *Stringocephalus* Beds (basal part), Kowala Formation; ?P. *ensensis* – P. *varcus* Zones.

Derivation of the name: from Latin tenuis – thin, diminutive.

Diagnosis. — Articular facet of the columnals nearly pentagonal in shape; areola reduced, weakly stellate; crenularium well-developed.

Material.— More than 140 colurnnals.

Dimensions of the holotype (in mm).— Facetal diameter (FD) 1,7; luminal diameter (LD)0,4; areolar diameter (AD)0,7; crenularial diameter (CD) 0,6; columnal height (KH) 0,5.

Description. — Columnal articula are pentagonal, strongly rounded in outline with facetal shape index (FSi) 90–93. Lumen is rather large, pentagonal to distinctly rounded. Areola is also pentagonal, with gently concave borders, surrounded by 30 to 35 straight and coarse, moderately long culmina. Columnals show straight and smooth lateral sides.

Remarks. — The species resembles commonly co-occuring K. *acutilobus* (Dubatolova 1975) but can be distinguished owing to reduced areola size, longer culmina and markedly rounded columnals at comparable ontogenetic stages. A clear gap separates ranges of morphologic variability of these species (Fig. 14C).

Occurrence. — See p. 18.

Family 'Pentagonomischidae' Le Menn 1988

Genus *Ricebocrinus* Le Menn 1988

Type species: Ricebocrinus *planus* Le Menn 1988.

Ricebocrinus parvus sp. *n.*

Fig. 9B–C.

Holotype: GIUS-4-139/12, Fig. 9B.

Type locality: Gora Sołtysia, set B, Holy Cross Mountains.

Type horizon: Jaźwica Member, Kowala Formation; earliest M. *falsiovalis* Zone.

Derivation of the name: From Latin parvus – minute, small.

Diagnosis. — Columnal articula pentagonal in shape; lumen pentagonal; areola reduced, pentagonal and surrounded by short culmina.

Material.— More than 80 columnals.

Dimensions of the holotype (in mm).— Facetal diameter (FD) 2.0; luminal diameter (LD) 0.4; areolar diameter (AD) 1.0; crenularial diameter (CD) 0.6; columnal height (KH)0.6.

Description. — Columnals are pentagonal, slightly rounded in outline, with almost straight lateral side, bearing five fine tubercules exaggerating their shape. Articular facet is flat, with facetal shape index (FSi) 89 to 91, and with pentagonal strongly rounded lumen. Crenularium is composed of straight, 30 to 35 moderately thick and uniformly-developed culmina. Moderately expanded areola exhibits regularly pentagonal rounded form.

Remarks. — The species differs from *R. planus* (Le Menn 1988) from the Frasnian of France by five lateral tubercules and from *R. kulagaiensis* (Dubatolova 1975) by thicker, longer culmina, and clearly reduced areola (see Fig. 14D).

Occurrence. — See p. 20.

Group Cyclici Moore & Jeffords 1968

Family 'Flucticharacidae' Moore & Jeffords 1968

Genus *Laudonomphalus* Moore & Jeffords 1968

Type species: Laudonornphalus regularis Moore & Jeffords 1968.

Laudonomphalus pinguicostatus sp. n.

Fig. 9E–F.

Holotype: GIUS-4-114/2, Fig. 9F.

Type locality: Siewierz, set BC, Silesia-Cracow Region.

Type horizon: Dziewki Beds, P. *varcus* – K. *disparilis* Zones.

Derivation of the name: From Latin pinguis – thick, costa – crenula, rib.

Diagnosis. — Columnals marked by an articular facet with coarse culmina and strongly reduced areola.

Material.— Eleven columnals.

Dimensions of the holotype (in mm).— Columnal diameter (KD) 1.4; facetal diameter (FD)1.3; luminal diameter (LD) 0.2; periluminal diameter (PD)0.1; areolar diameter (AD) 0.1; crenularial diameter (CD)0.9; columnal height (KH)0.4.

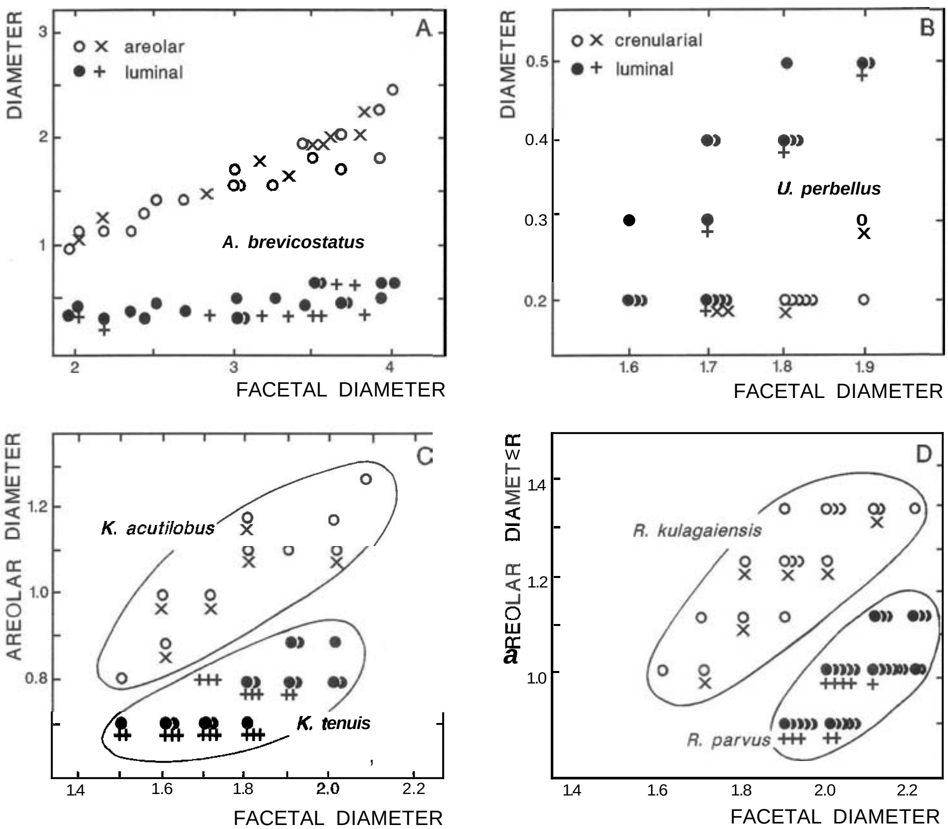


Fig. 14. Plots of basic columnal parameters. Measurements from type localities marked by crosses. CIA. Anthinocrinus brevicostatus sp. n. from Laskowa Gora Beds: Laskowa Gora A and Górno A (typelocality). OB. *Urushicrinus perbellus* sp. n. from Jaźwica Member: Poslowice B, Marzysz B and from Crinoid-Coral Level: Sowie Górki C (type locality). ❑C. *Kasachstanocrinus* acutilobus Dubatolova 1975 and *Kasachstanocrinus* tenuis sp. n. from Jaźwica Member: Jaźwica B and from *Stringocephalus* Beds: Jurkowice A (type locality of K. tenuis sp. n.). OD. Ricebocrinus kulagaiensis (Dubatolova 1975) and Ricebocrinus paruus sp. n. from Jaźwica Member: Jaźwica B and Góra Sołtysia B (type locality of R. paruus sp. n.).

Description.—These diminutive, circular columnals with gently convex and smooth lateral sides have flat to slightly concave articular facets. Lumen is pentagonal to stellate, bordered by a rather broad perilumen. Culmina are long, thick and dichotomous, range from 12 to 20 in number. The lumen size is more constant than crenularium width during ontogenetic growth (Fig. 15A). Areola is very small, in some cases hardly perceptible.

Remarks.— The main difference between the species and similar L. *celticus* (Le Menn 1985) from the Siegenian of France, is its proportionally wider lumen, as well as coarser and marginally bifurcated culmina.

Occurrence.—Type locality only.

Family 'Schyschcatocrinidae' Dubatolova 1971

Genus *Schyschcatocrinus* Dubatolova 1971

Type species: Pentagonocyclicus *astericus* Schewtschenko 1966.

Schyschcatocrinus delicatus sp. *n.*

Fig. 10C–D.

Holotype: GIUS-4-146/1, Fig. 10C.

Type locality: Gora Zamkowa, set C, Chęciny, Holy Cross Mountains.

Type horizon: Chęciny Limestone (lower part), Kowala Formation; M. *falsiovalis* Zone.

Derivation of the name: From Latin delicatus – delicate, weak.

Diagnosis. — Minute columnals with flattened articular facet, broad areola and narrow crenularium.

Material.— More than 1500 columnals.

Dimensions of the holotype (in mm).— Facetal diameter (FD) 1.5: luminal diameter (LD) 0.3; crenularial diameter (CD) 0.6; areolar diameter (AD) 0.6; columnal height (KH) 0.4.

Description. — Lateral sides of these delicate columnals are smooth and straight, although some the largest specimens may have very fine ornamentation. The flat articular facet is perforated by pentagonal lumen surrounded by well-developed smooth areola. Crenularium is composed of 20 to 25 unbranched, rather coarse culmina.

Remarks. — The new species differs from the most similar *S. creber* (Dubatolova 1975) from the Givetian of Russia in having shorter culmina and distinctly wider areola at comparable ontogenetic stages (Fig. 15B). In my earlier papers (Gluchowski 1981a, b), this morphotype from some sites was incorrectly included in *S. creber,* as the youngest growth stage.

Occurrence. — See p. 22.

Schyschcatocrinus multiformis sp. *n.*

Fig. 10J-L.

Holotype: GIUS-4-196/23, Fig. 10J.

Type locality: Jozefka Hill near Gomo, set A, Holly Cross Mountains.

Type horizon: Laskowa Gora Beds; K. *disparilis* Zone.

Derivation of the name: From Latin multiformis - multiform; because of variable columnals outline.

Diagnosis. — Ban-el-shaped columnals marked by ornamented lateral side and articular facet with narrow crenularium.

Material.— More than 850 columnals.

Dimensions of the holotype (in mm).— Columnal diameter (KD) 4.4; facetal diameter (FD) 3.3; luminal diameter (LD) 0.5; areolar diameter (AD) 1.8; crenularial diameter (CD) 1.0; columnal height (KH) 4.3.

Description. — The stem is probably heteromorphic or xenomorphic. Columnals are differentiated in heigth, moderate low to high (see Fig. 15C), and are less or more barrel-shaped. At the mid-heigth of the lateral side of most of them there are distinct bulges and/or tubercles variable in size and number (3 to 10), and which are not always spaced regularly. Exceptionally, the lateral side may be almost smooth. The flattened

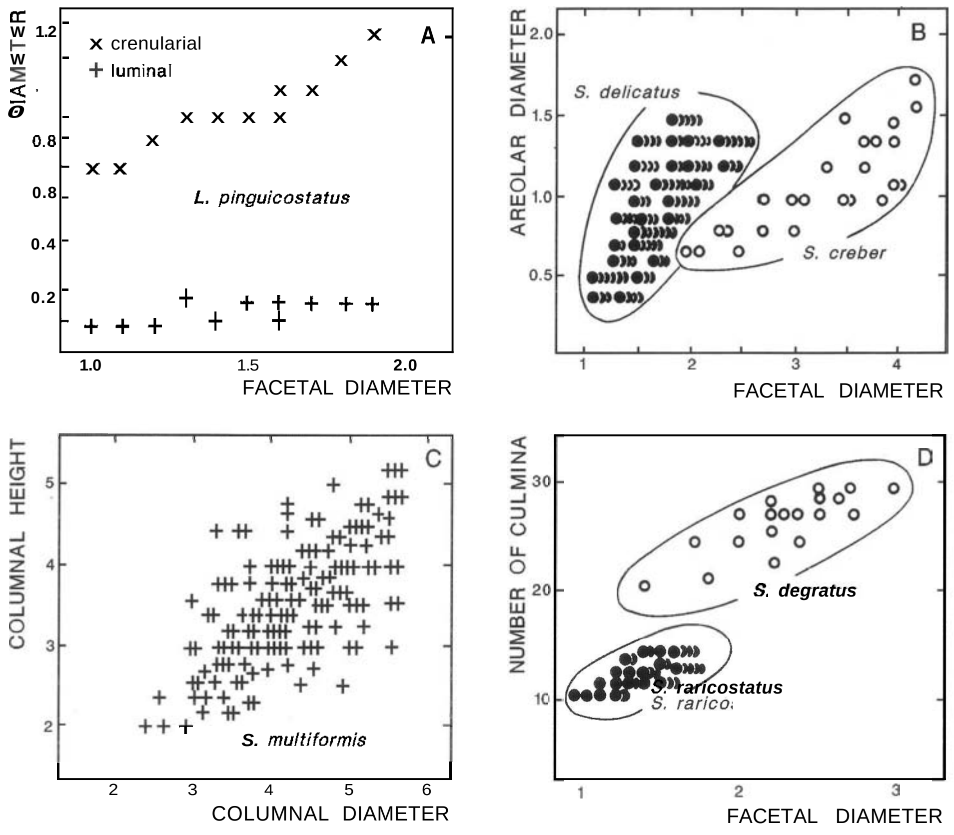


Fig. 15. Plots of columnal parameters of some crinoid species from selected samples. Measurements from type localities marked by crosses. ❑A. Laudonornphalus pinguicostatus sp. n. from Dziewki Limestones: Siewierz RC (type locality). OR. *Schyschcatocrinus creber* Dubatolova 1975 and Schyschcatocrinus delicatus sp. n. from Crinoid-Coral Level: Sowie Górki C. OC. Schyschcatocrinus *multiformis* sp. n. from Laskowa Góra Beds: Gorno A (type locality). OD. Stenocrinus degratus Dubatolova 1975 and Stenocrinus raricostatus sp. n. from Dziewki Limestone: Siewierz BC.

articular facet is characterized by a pentagonal, rounded lumen, wide areola, and coarse, short culmina which range from 18 to 23 in number.

Remarks.— The species resembles S. *spinosus* (Le Menn 1985) from the Emsian of France, but differs in relatively shorter culrnina and a more differientiated morphology of the lateral surface.

Occurrence.— see **p. 24.**

Family 'Stenocrinidae' Dubatolova 1971

Genus *Stenocrinus* Dubatolova 1971

Type species: Stenocrinus *bifurcatus* Dubatolova 1971.

Stenocrinus raricostatus sp. *n.*

Fig. 11A.

Holotype: GIUS-4-126/10, Fig. 11A.

Type locality: Jurkowice-Budy, set A, Holy Cross Mountains.

Type horizon: *Stringocephalus* Beds (basal part), Kowala Formation: *?P. ensensis – P. varcus* Zones.

Derivation of the name: From the Latin rarus – rare, costa – crenula, rib.

Diagnosis. — Columnals with subcircular lumen surrounded by narrow areola and coarse, infrequent culmina.

Material.— More than 480 columnals.

Dimensions of the holotype (in mm).— Facetal diameter (FD) 1.2; luminal diameter (LD) 0.1; areolar diameter (AD) 0.4; crenularial diameter (CD) 0.7; columnal height (KH) 0.3.

Description. — Very delicate columnals show a smooth (in some specimens slightly convex) lateral side. The articular facet is perforated by a small, pentagonal, strongly rounded lumen. The areola is not very extensive, flattened and circular or rarely gently pentagonal in outline. Moderately wide crenularium is composed of 11 to 15 thick and unbranched culmina.

Remarks. — This is a very common species, closely related to S. *degratus* (Dubatolova 1975) from the Late Eifelian of Russia. The distinctive characters of the Polish species is strongly diminished columnal size in combination with coarser and less numerous culmina. These minute columnals from some localities were previously (Głuchowski 1981a, b) treated as the earliest ontogenetic stages of S. *degratus* but this could not be the case because a clear gap separating range of morphologic variability of these species (Fig. 15D).

Occurrence.— See p. 26.

Genus *Calleocrinus* Dubatolova 1971

Type species: Pentagonocyclicus *granatus* Dubatolova 1964.

Calleocrinus kielcensis sp. *n.*

Fig. 11G–I.

Holotype: GIUS-4-200/10, Fig. 11H.

Type locality: Wola Quarry near Kowala, set G, Holy Cross Mountains.

Type horizon: Detrital Limestone, P. jarnieae – *?P. rhenana* Zones.

Derivation of the name: From Kielce, the main city in the Holy Cross Mountains.

Diagnosis. — Articular facet of low columnals marked by extremely minute lumen, and crenularium composed of numerous, long, branched culmina.

Material.— More than 550 columnals and 20 stem fragments.

Dimensions of the holotype (in mm).— Facetal diameter (FD) 5.0; luminal diameter (LD) 0.1; crenularial diameter (CD) 4.9; columnal height (KH) 0.8.

Description. — These are heteromorphic stems with two orders of insignificantly differentiated columnals (pseudohomomorphic). Columnals are low with straight or gently convex lateral side. Articular facet is flat and covered completely with many usually strongly dichotomous culmina. Lumen is very minute, stellate to circular.

Remarks. — The species is closest to C. *multicius* (Dubatolova 1964) from the Frasnian of Russia, but can be distinguished owing to relatively smaller columnal height and less prominent differentiation of columnals within the stem.

Occurrence.—See p. 26.

Calleocrinus bicostatus sp. n.

Fig. 11J–K.

Holotype: GIUS-4-93/1, Fig. 11K.

Type locality: Kadzielnia, set A at Kielce, Holy Cross Mountains.

Type horizon: Kadzielnia Limestone Member of the Kowala Formation; P. *transitans* - P. punctata Zones.

Derivation of the name: From Latin bis – twice, costa – crenula, rib; because of bizonal crenulation.

Diagnosis.— Articular facet of the columnals flat, with bizonal crenularium and small lumen.

Material.— Eleven columnals and **3** stem fragments.

Dimensions of the holotype (in mm).— Facetal diameter (FD)6.2; luminal diameter (LD)0.4; crenularial diameter (CD)5.8; columnal height (KH) 1.0.

Description.—These heteromorphic stems contain low columnals of only two(?) orders. Flat articular facets have strongly reduced, stellate to circular lumen. Crenularium is bizonal due to significantly diversifield culrnina. The internal zone, extending as far as 2/3 to 1/2 of radius, is formed by straight, relatively coarser and rare culmina commonly reaching the central canal, but in some cases only weakly visible near the lumen. External culmina are strongly dichotomous, very numerous and thin. The passage between the zones is more or less sharp.

Remarks.— A general stem structure of the species may suggest some connection with that of associated C. *kielcensis* sp. n. However, the lumen of C. bicostatus sp. n. shows a somewhat bigger size at comparable ontogenetic stages (see Fig. 16A) and the development of the bizonal crenularium is a unique characteristic among all other species of the genus. Moreover, no specimen showing any transitional features between both types of articula have been found.

Occurrence.— See p. 26.

Family 'Asperocrinidae' Stukalina 1975

Genus Asperocrinus Stukalina 1975

Type species: Asperocrinus giganteus Stukalina 1975.

Asperocrinus brevispinosus sp. n.

Fig. 12K.

Holotype: GIUS-4-114/11, Fig. 12K.

Type locality: Brudzowice-Dziewki Hill, north of Siewierz, set BC; Silesia-Cracow Region.

Type horizon: Dziewki Limestones P. *varcus* – K. disparilis Zones.

Derivation of the name: From Latin brevis – short, spinosus – spiky.

Diagnosis.— Columnals with coarse culmina on articular facet and one row of fine spines on the lateral side.

Material.— Fifty four columnals.

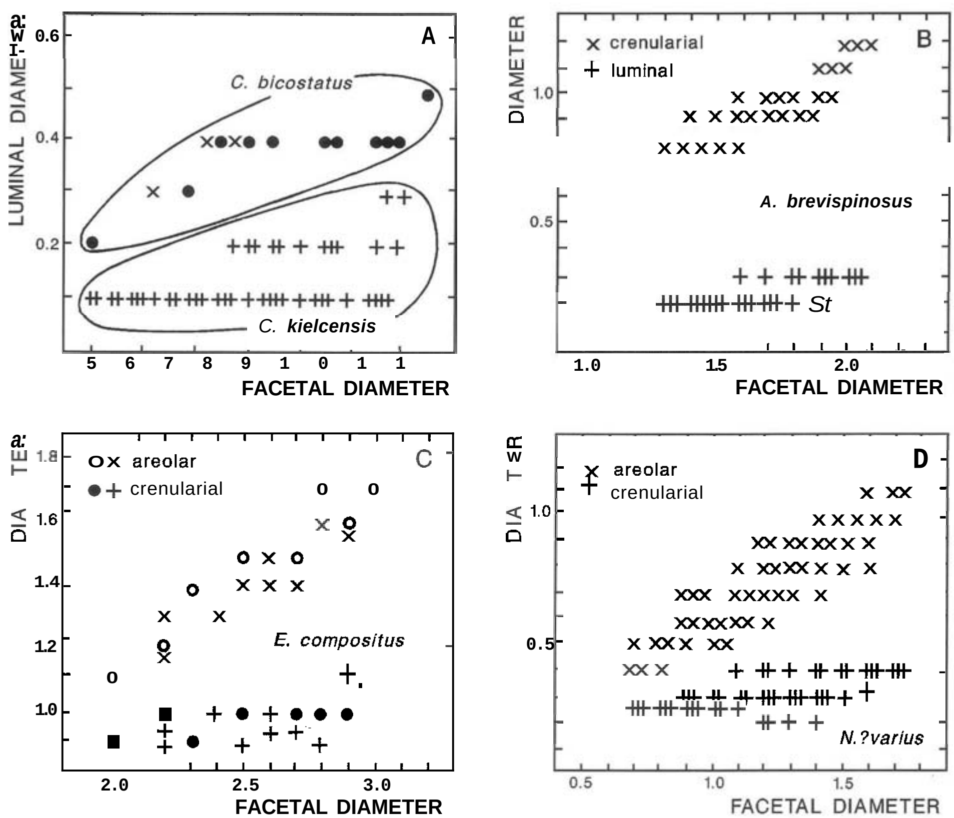


Fig. 16. Plots of basic columnal parameters. Measurements from type localities marked by crosses. ❑A. Calleocrinus bicostatus sp. n. from Detrital Beds of Kadzielnia B, Sitkówka-Jaźwica BC, Panek B and Kadzielnia Member at Kadzielnia A (type locality) and Calleocrinus kielcensis sp. n. from Detrital Beds at Kowala G (type locality). ❑B. Asperocrinus brevispinosus sp. n. from Dziewki Limestone, Siewierz BC (type locality). ❑C. Exaesiodiscus cornpositus sp. n. from Detrital Beds of Kowala G and Sitkówka-Jaźwica BC (type locality). OD. *Noctuicrinus ?varius* sp. n. from *Stringocephalus* Beds, Jurkowice A (type locality].

Dimensions of the holotype (in mm).— Facetal diameter (FD) 1.5; luminal diameter (LD) 0.2; areolar diameter (AD) 0.4; crenularial diameter (CD) 0.9; columnal heihgt (KH) 0.6.

Description. — Very small circular columnals are marked by straight latera bearing 12 to 15 minute spines or tubercles arranged regularly in the mid-height of a columnal. A flat articular facet is covered with 15 long, straight and relatively thick culmina. Lumen is moderate in size and circular, surrounded by small areola located in a central depression that rises toward axis. The lumen size is more constant than crenularium width during ontogenetic growth (Fig. 16B).

Remarks. — As for the shape of the articular facet, the new species closely resembles A. *radiatus* (Le Menn 1980) from the Siegenian of France. The only difference consists in a one-row distribution of spines in A. ***brevispi-***

nosus sp. n. Another Siegenian species, A. *annulatus* (Le Menn 1976), can be distinguished from the Polish species by significantly longer spines on the latera and relatively smaller lumen.

Occurrence.—See p. 28.

Family 'Exaesiodiscidae' Moore & Jeffords 1968

Genus *Exaesiodiscus* Moore & Jeffords 1968.

Type species: *Exaesiodiscus acutus* Moore & Jeffords 1968

Exaesiodiscus compositus sp. *n.*

Fig. 13J–K.

Holotype: GIUS-4-10/ **1**, Fig. 13K.

Type locality: Sitkówka-Jaźwica, sets BC, Holy Cross Mountains.

Type horizon: Detrital Limestone: P. *rhenena* Zone.

Derivation of the name: From Latin compositus – complex: because of the heteromorphic type of stem

Diagnosis.—Discoidal nodals distinguished by pointed epifacet; articular facet with small lumen and coarse culmina.

Material.– Fourteen columnals and **3** stem fragments.

Dimensions of the holotype (in mm).— Columnal diameter (KD) 4.8 – nodal, 3.0 – internodal; facetal diameter (FD) 2.8; epifacet diameter (ED) 2.0 – nodal, 0.2 – internodal; luminal diameter (LD) 0.2; areolar diameter (AD) 1.7; crenularial diameter (CD) 0.9; columnal height (KH) 1.2.

Description.—These heteromorphic stems are composed of disc-shaped nodals and markedly narrower internodals. Height of nodals equals or slightly exceeds internodals. Large epifacet terminantes laterally with a sharp margin. Articular facet characterized by flat surface with a minute lumen surrounded by broad areola and narrow crenularium consisting of 25 to 28 short, unbranched culrnina. The areola shows more notable size increase during ontogenetic growth, than crenularium (Fig. 16C). Lateral side of internodals is straight or gently convex, without ornamentation.

Remarks.— The new species resembles *E. minutus* (Moore & Jeffords 1968) from the Givetian of New York, but can be distinguished owing to coarse culrnina and pointed (instead of rounded) epifacet.

Occurrence.— See p. 28.

Family Tantalocrinidae' Le Menn 1985

Genus *Noctuicrinus* Le Menn 1985

Type species: *Noctuicrinus chrankensis* Le Menn 1985.

Noctuicrinus? varius sp.

Fig. 13A.

Holotype: GIUS-4-126/1, Fig. 13A.

Type locality: Jurkowice-Budy, set A, Holy Cross Mountains.

Type horizon: *Stringocephalus* Beds (basal part), Kowala Formation: ?P. *ensensis* – P. *varcus* Zones.

Derivation of the name: From Latin varius – variable, changeable.

Diagnosis.— Articular facets pentagonal to circular in outline; culmina coarse; lateral side of columnals ornamented.

Material.— Forty nine columnals.

Dimensions of the holotype (in mm).— Columnal diameter (KD) 1.3; facetal diameter (FD)1.1; luminal diameter (LD)0.2; areolar diameter (AD) 0.5; crenularial diameter (CD)0.4; columnal height (KH) 0.7.

Description. — These heteromorphic, delicate stems are composed of distinctly pentagonal nodals, and strongly rounded (to circular) internodals. Nodals latera are convex and marked by blunt keels, crests and/or 5 nodes; they display only one cirral scar, which may be completely missing (nudinodals). Very fine cirral pores, 1 to 5 in number, indicate reduction of cirri in some specimens. Most nodals are pentagonally outlined, with strongly concave articular facets bordered by short culmina. Some internodals (? of higher orders) are more rounded and have flattened articular facets which correspond to central depressions on nodals or lower-order internodals. The number of thick and short culmina ranges from 20 to ***23.*** Lumen is rather small, stellate, pentagonal to strongly rounded. Areola shows more notable sue increase than lumen during ontogenetic growth (Fig. 16D).

Remarks. — The species shows great variability in columnal shapes. The form and sequence of columnals within the stem resembles that of N. *chrankensis* (Le Menn 1985) from the Late Emsian of France but differs in pentagonal outline and/or weakly concave articular facets and less numerous cirri. The strict pentaradial symmetry of some articular facets may make the assignement to the genus *Noctuicrinus* questionable.

Occurrence. — Type locality only.

Methods of analysis of crinoid assemblages

There are two crucial points in restoring the original composition of Paleozoic crinoid communities on the basis of fossil assemblages: (1) biological reliability of the crinoid stems taxonomy and (2) taphonomic bias.

A rapid post-mortem disintegration of crinoid skeletons in the absence of rapid burrial is unquestionably the dominant factor in their preservation (Cain 1968; Meyer 1971; Ruhrmann 1971b; Liddel 1975). The presence of solely separate echinoderm ossicles in the sediments does not necessarily indicate their post-mortem transportation (Meyer & Ausich 1983; Meyer & Meyer 1986), although Ruhrmann (1971a, b) suggested that fragmented stems may buoy before the soft tissue completely decayed. In a turbulent environment even articulated crinoids can undergo some transport prior to the final burial (Meyer *et al.* 1989). Nevertheless, it seems that generally an occurence of articulated or only partially disarticulated skeletons excludes their distant transportation over the living site. Even paraautochtonous or allochtonous accumulations may preserve, to some degree, some information on the original taxonomic structure. Only a selective sorting of ossicles in respect to their size and

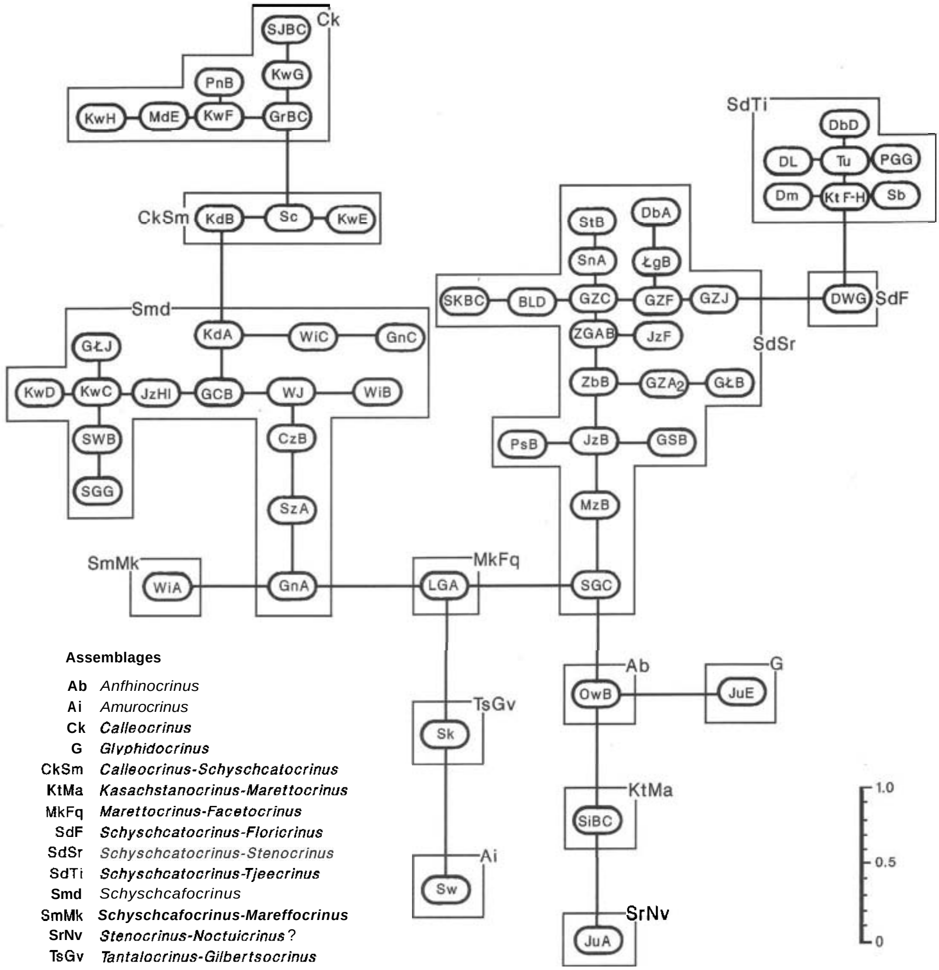


Fig. 17. Crinoid assemblages derived by grouping of sample localities using the analysis of taxonomic affinity index. Cutoffvalue 0.40. For explanation of the localities symbols see Fig. 2.

shape, after the loss of organic matter, may eventually destroy all their taxonomic value.

Incomplete disarticulation and lack of sorting of ossicles in the most of samples analysed herein suggest that they represent accumulations in close proximity to the original biotopes. Some of them are in situ catastrophic assemblages, for instance the Laskowa Gora A locality with complete skeletons showing rapid burial associated with still attached discoidal holdfasts (see Racki et *al.* 1985: Pl. 12: 4b, c). Sowie Gorki C, Kowala G, and Sitkówka-Jaźwica BC localities show signs of more prolonged burial. Redeposition and sorting are evident in some other sites, for instance Sitkowka-Kowala B, Gora Zamkowa C, and Jaźwica F.

The whole recoverable and identifiable crinoid material useful for taxonomic analysis was gained exclusively by bulk and/or surface samp-

Tab. 1. General characteristics of the crinoid assemblages recognized herein. Symbols as in Fig. 17.

Assem-blage	Dominant Taxa	Average Percentage	Number of Taxa	Average Diversi-ty Index	Dominant Facies
Ab	*A. brevicostatus*	29.4	8	6.68	platform (shoal)
Ai	*A. imatschensis*	73.7	6	1.80	terrigenous
Ck	*C. kielcensis*	83.2	13	1.47	reef to slope
CkSm	*C. kielcensis* *S. multiformis*	41.5 25.5	9	3.83	reef to slope
G	*Glyphidocrinus*	30.8	8	5.90	platform (shoal)
KtMa	*K. tenuis* *M. angustannulus*	22.2 16.1	17	8.30	platform (shoal-intershoal)
MkFq	*M. kartzevae* *F. quinqueangularis*	20.7 15.5	30	11.54	slope to open shelf
Smd	*S. multiformis* *S. delicatus*	47.7 24.0	37	3.62	open shelf to reef
SdF	*S. delicatus* *Floricrinus*	36.7 26.7	6	3.97	open shelf
SmMk	*S. multiformis* *M. kartzevae*	39.9 16.9	18	8.76	slope
SdSr	*S. delicatus* *S. raricostatus*	60.9 16.1	22	2.70	plafform (shoal-intershoal)
SdTi	*S. delicatus* *T. insectus*	42.5 36.9	6	3.12	open shelf to slope
SrNv	*S. raricostatus* *N.? varius*	42.3 29.2	7	3.54	plafform (intershoal)
TsGv	*T. scutellus* *G. vetulus*	25.2 14.1	29	8.90	slope to open shelf

ling techniques. It comprises specimens being both free from sediment and stuck in the solid matrix. Thus, the data base (data matrices are available on reqest) refers to mostly cumulative collections. Both long stem fragments and single columnals as well as crown parts were counted as single specimens. This, although being an obvious simplification, allows comparison of relative frequency of species between samples. Crinoid assemblages were distinguished using Q-mode analysis to all sixty samples. To quantify comparisons the index of taxonomic affinity (= taxonomic distance 'd') was employed. It was calculated for each pair of the samples according to formula:

$$d = \sum_{t=1}^{m} \frac{|x_{it} - x_{jt}|}{200}$$

where, m – number of considered taxa; x_{it} and x_{jt} – percentage of t-taxon in i-and j-samples (see Alexandrowicz 1977). The value of the index ranges from 0 (for taxonomically identical samples) to 1 (for totally different ones).

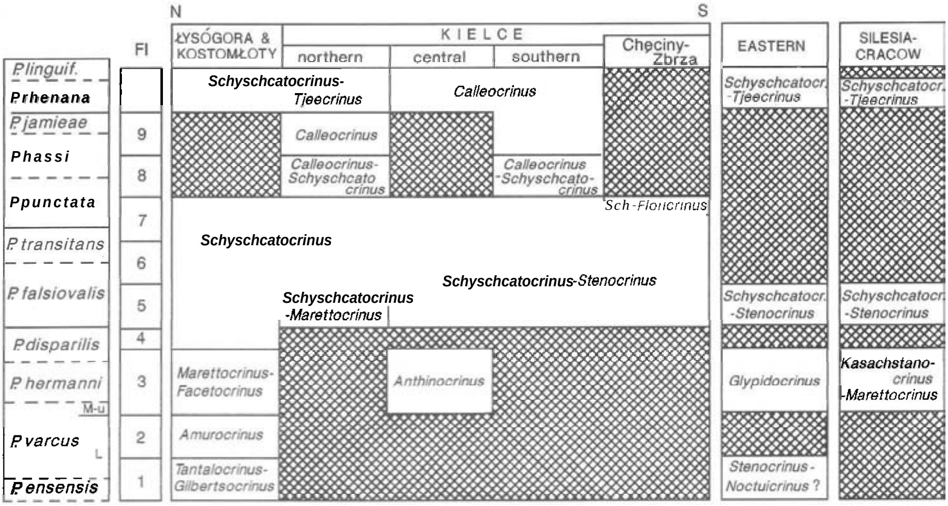


Fig. 18. Distribution of Givetian-Frasnian crinoid assemblages in the Holy Cross Mts and Silesia-Cracow Region. FI: faunal intervals.

The samples were ordered in a dendrite according to the level of affinity (Perkal 1959). Taking the cutoff value of similarity measure at the 0.40 level, fourteen sample groups can be identified. They represent crinoid assemblages defined by predominant taxa (Fig. 17). Such a 'taxonomic structure' based on original. untransformed data, shows direct similarities both among particular assemblages and within them. For general characteristics of recognized assemblages [Tab. 1). the E.H. Sirnpson's (1949) diversity index (DI) was counted according to the formula:

$$DI = \frac{N\,(N-1)}{\sum_{t=1}^{m} n_t\,(n_t - 1)}$$

where, m – number of taxa in the sample: N – total number of specimens in the sample; n_t – number of specimens of t-taxon.

The faunal interval concept (see Johnson 1977) may allow us to identify temporal series of discrete crinoid faunas in independent time-stratigraphic units. In the studied Givetian to Frasnian sequence of the Holy Cross Mountains ten such intervals, based on distributional pattern of the crinoid assemblages are represented (Fig. 18).

Evolution of crinoid communities

Crinoids are an essential element of the shallow-water open shelf macrobenthic faunas of the Givetian-Frasnian sequence of the Holy Cross Mountains and Silesia-Cracow Region (Crinoid and Echinoderm Assemblages of Racki 1993). They are a reliable indicator of environmental

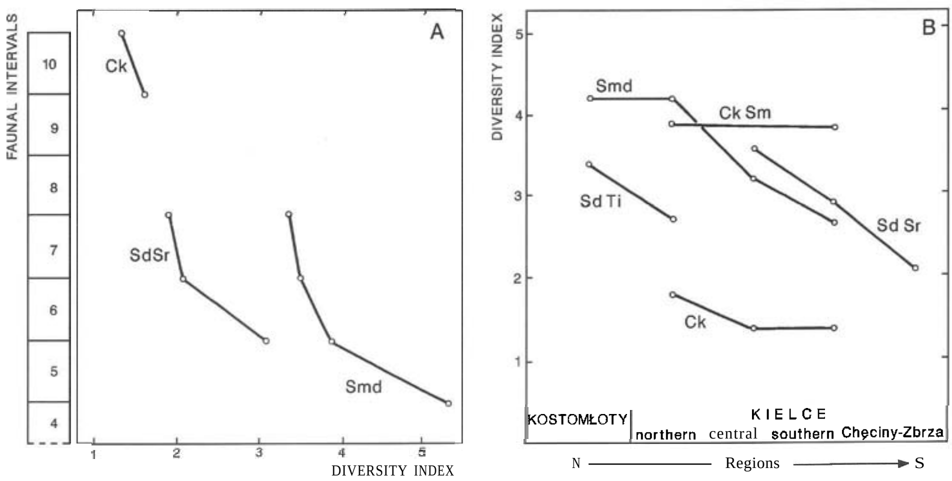


Fig. 19. Taxonomic diversity changes within long-ranging (A) and wide-distributed (B) crinoid assemblages. For explanation of the assemblages symbols see Fig. 17.

changes, as exemplified by the general decrease of diversity index in the studied sequence (Fig. 19A). This trend coincides with increasing importance of predominant taxa. This is particularly apparent in *Schyschcatocrinus* (FI 4–6) and *Schyschcatocrinus-Stenocrinus* (FI 5–6) assemblages (Fig. 20). The data suggest general, gradual worsening of life conditions. The dominant species were probably less sensitive enviromentally and therefore their population densities were increasing.

Reduced taxonomic diversity of crinoid assemblages in the southern part of the Holy Cross Mountains area (Fig. 19B) resulted from more restricted marine environments (with salinity and temperature fluctuations and high calcium concentration) within the middle carbonate shelf (Racki 1986, 1988, 1993). This tendency is also visible in decrease of the overall taxonomic diversity of the crinoid faunas within particular regions (Tab. 2), which reflects their different facies development. Contrasting facies types correspond to environments with completely different benthic biotas, e.g. 'reef community-complex' and 'level-bottom community' of Boucot (1983). Generally, it can be accepted that a broadly-defined reef-complex is represented in the Kowala Formation (Narkiewicz et *al.* 1990) which includes various shallow-water biostromes, and biohermal structures. Coarse-grained varietes of the Frasnian 'reef cap' and proximal fore-reef facies of the Detrital-Stromatoporoid Beds (Racki 1993), are also represented in the area. Dziewki and Dębnik Limestones of the Silesia-Cracow Region were also deposited in connection with reefs. All the remaining types of the sediments in the studied area, including deeper-slope and open-shelf facies, represent the level-bottom environment.

Only a few crinoid species reveal distinctive preferences to even such broadly defined major environments. Among them, *Marettocrinus kartze-*

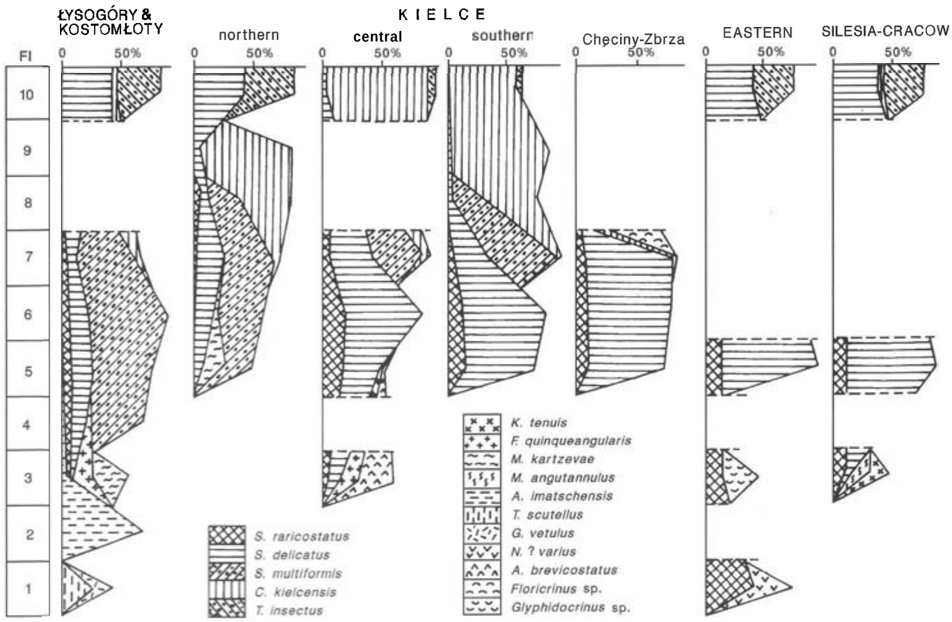


Fig. 20. Relative frequencies of predominant crinoid taxa in the regions studied. FI: faunal intervals.

vae, *Tantalocrinus scutellus*, *Gilbertsocrinus vetulus*, and *Amurocrinus imatschensis* were limited in distribution to level-bottom environments, while *Noctuicrinus*? *varius*, *Kasachstanocrinus tenuis*, *Ricebocrinus parvus*, and *Urushicrinus perbellus* occur solely in reef-complexes. Other taxa had weaker facies links. Faunal differences between both kinds of the environmental settings are more obvious (Fig. 21) in the older part of the sequence (platform. pre-reef phase; Szulczewski 1971; Narkiewicz 1988; Racki 1988, 1993). The greatest taxonomic diversity of the crinoids was reached in some level-bottom environments of the Middle Devonian platform stage. During sedimentation of the Skały Beds, Laskowa Gora Beds, Szydłówek Beds. and Lower Wietrznia Beds suitable open-marine conditions developed. These environments were inhabited by forms of variables sizes, frequently represented by large-sized species. Stems of many of them were attached to the substrate with various appendages or modified nodal epifacets (creeping stems of Franzen 1977 and stoloniferous holdfasts of Brett 1981) e.g. *Marettocrinus kartzevae*, *Praeorocrinus polonicus*, *Schyschcatocrinus multiformis*, and (?)*Cycloocetocrinus multigranulatus* or they were distally coiled (distal coils *sensu* Brett 1981) like in *Gilbertsocrinus vetulus*, *Eocamptocrinus fragilis*, *Myelodactylus canaliculatus*. Probably only few forms were cemented to bottom hard objects (discoidal holdfasts of Brett 1981) e.g. cupressocrinids or rooted in a soft substrate (rhizoidal holdfasts of Brett 1981) e.g. *Trybliocrinus*. According to Breimer (1978), a permanent attachment to the floor was typical of rheophobic or

Tab. 2. Generalized taxonomic diversity of crinoid faunas within the regions studied.

Region	Total Number of Taxa	Cosmopolitan Taxa		Average Diversity Index
		number	%	
Łysogóry	34	20	58.8	5.35
Kostomłoty	43	22	51.2	4.89
Northern Kielce	31	13	41.9	4.30
Central Kielce	30	13	43.3	3.67
Southern Kielce	26	10	38.5	2.38
Chęciny-Zbrza	15	7	46.7	2.44
Eastern	19	10	52.6	3.57
Silesia-Cracow	22	11	50.0	4.50

rheophilic crinoids passively oriented in water currents. *Trybliocrinus* mentioned above, may be regarded as rheophobic form adapted to slack water or slight flow water (Breimer & Webster 1975). Rheophilic crinoids comprise also species of *Platycrinites,* minute *Ammonicrinus* (Kongiel 1958; Piotrowski 1977) and *Hapbcrinites* (Le Menn 1985). Co-occurrence of rheophilic and rheophobic forms generally points to the profound hydrodynamic differentation of the level-bottom environments typified by current-affected and stagnant (sheltered) zones adjoining to each other. Furthermore, prominent difference in magnitude of co-existing species suggests profound tiering effect and niche differentiation in the crinoid communities (see Ausich 1980; Meyer & Ausich 1983; Ausich & Bottjer 1985). The higher energy depositional regime of the Świętomarz Beds (Kłossowski 1985; Orłowski & Radwański 1986), is exceptional in a low taxonomic differentiation of the crinoid fauna dominated by *Arnurocrinus imatschensis*.

In environments less suitable for crinoids, common in the Givetian stromatoporoid-coral platform, increased mortality resulted in preservation of small-sized specimens (see Głuchowski 1986). The species most common there had smooth stems without cirri. They were thus attached to the bottom with some kinds of terminal holdfasts. Only few forms show the ability to be secondarily attached to a soft substrate with cirri (e.g. *Noctuicrinus*; see Le Menn 1985: p. 175, Fig. 72). This may suggest that these crinoids dwelled in sheltered depressions at the bottom. Exceptionally raised taxonomic and ecologic diversity can be seen in the Crinoid-Coral Level (Sowie Górki C) and Dziewki Limestone (Siewierz BC). The faunal diversity decreased towards the termination of the platform phase both in the level-bottom and organic buildup environments.

The development of the Frasnian Dyminy reef, was manifested in a decrease of taxonomic distinctions between crinoid assemblages of both of the principal environments. Raised water turbulency was typical of the Frasnian shallow-water environments (Kaźmierczak 1971; Narkiewicz *et al.* 1990) and this probably resulted in a lesser abundance of *Schyschca-*

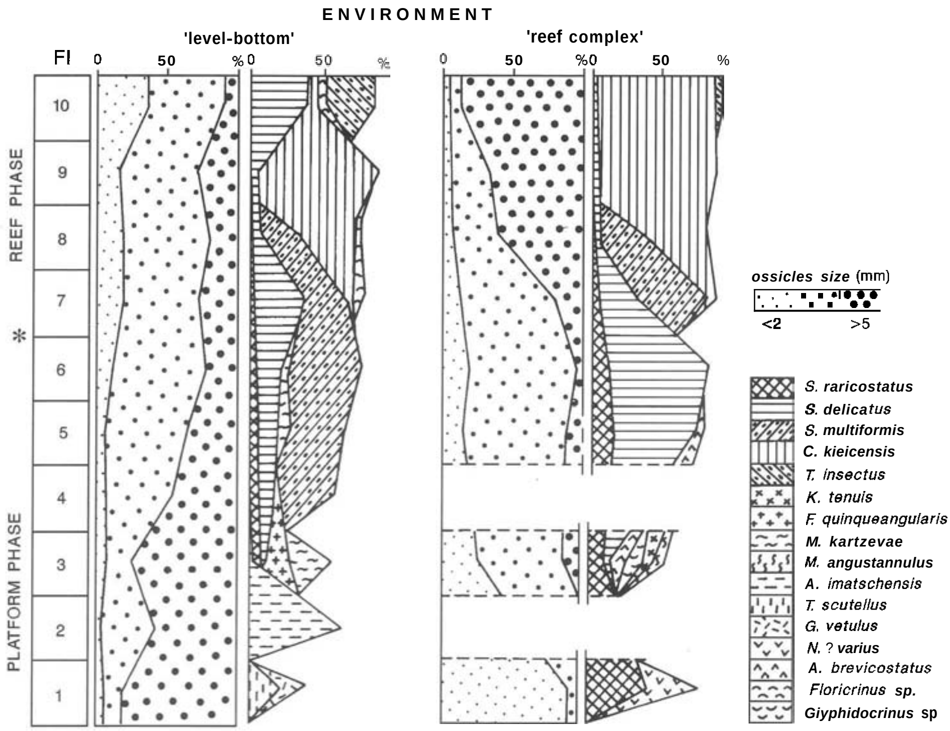


Fig. 21. Relative frequencies of predominant crinoid taxa and ossicle sizes in two major environmental settings types. FI: faunal intervals.

tocrinus delicatus, as well as the southward expansion of *Schyschcatocrinus multiformis*. Among newly introduced crinoids two major morphological trends were evident. The first one was connected with the development of forms with thick and stout stems, such as *Calleocrinus kielcensis*. The species appeared in the whole Holy Cross Mountains area and its contribution gradually increased up to a full predominance, particularly in the reef-complex. The second tendency was manifested in melocrinids which had strong arms, partly or completely fused into brachial trunks. They were equipped in massive stems, permanently attached to the sea floor with rhizoidal holdfasts. Lane (1971) considers such morphological adaptations typical of reef-related crinoids. Massive, stout stems and highly specialized arms are characters of rheophobic species that exploited probably non-directional turbulent currents or slack-water biotopes within the reef infrastructure (Breimer & Webster 1975). However, the persistent domination of melocrinids and calleocrinids also in the level-bottom environment indicates low to moderate energy conditions.

The decline of the Dyminy reef development is marked by a rapid increase of differences between crinoid faunas of both major environments. The mass occurrence of *Tjeecrinus insectus* and the renewed predominance of *Schyschcatocrinus delicatus* in the level-bottom environment are expressions of this phenomenon.

In general terms, the level-bottom crinoid faunas revealed higher levels of taxonomic and ecologic diversity than the reef-complex, in particular during the Givetian platform phase. This difference became less apparent during the Frasnian phase, which suggests some deterioration of crinoid life conditions. Reef-related assemblages were not so much effected by it. Nevertheless, profound changes are recognizable in the composition of shallow-water crinoid faunas.

Dynamics of the crinoid faunas

Established diversity trends and stratigraphic distribution of the crinoid faunas correspond (Fig. 22) to the sequence of transgressive-regressive (T-R) cycles (Johnson *et al.* 1985). Such extrabasinal control by eustatic events is manifested in major depositional cyclicity during the Givetian and Frasnian of the Holy Cross Mountains (Racki 1985b, 1988, 1993).

Crinoid diversity rises are associated with the deepening pulses of T-R cycles IIa, IIc and IId, while its falls correlate with the regressive interphases (see FI 2, FI 5–6 and FI 9). The sole departure is seen in a distinct diversity lowering (FI 4) connected with the Late Givetian onlap IIb. This tendency among crinoids seems to confirm the opinion of Ebert (1992) that there was an overall drop in diversity among various faunal groups in the transgressive phase beginnig of T-R cycle IIb.

The following deepening pulses resulted also in a gradual southward migration of the Holy Cross Mountains crinoid faunas. This is best exemplified by *Schyschcatocrinus multiformis,* first noted in the Kostomłoty area, later introduced to the Northern Kielce Region, and last installed in the Central and Southern Kielce regions after the transgression IIc. Furthermore, the initiation of T-R cycle IIb is linked with the appearance of *Marettocrinus kartzevae* in the Northern Kielce Region; the species was found earlier in the Kostomloty and Eysogory domains. Notably, also cupressocrinids colonized the Central and Southern Kielce regions in this very time interval. In addition, the crinoid faunas of the northern areas display a generally more cosmopolitan character, because of many affinities with distant areas of Eastern Europe and Central Asia (Kuznieck Basin, the Urals, Altai, Kazakhstan), as well as with the Variscan Europe (Armorican Massif, the Eifel, Ardennes, Cantabrian Mountains). The pattern corresponds to the biogeographically transitional position of the Holy Cross Mountains (Racki 1988), and the amount of widely distributed species diminished progressively in southern crinoid faunas (see Tab. 2). And last, most of more cosmopolitan taxa had indeed their first established appearance in the northern basin domain, but none in the southern (Kielce) platform.

Fig. 22. Generalized stratigraphic distribution of Givetian-Frasnian crinoids in the Holy Cross Mts and Silesia-Cracow Region within respective faunal intervals (FI).

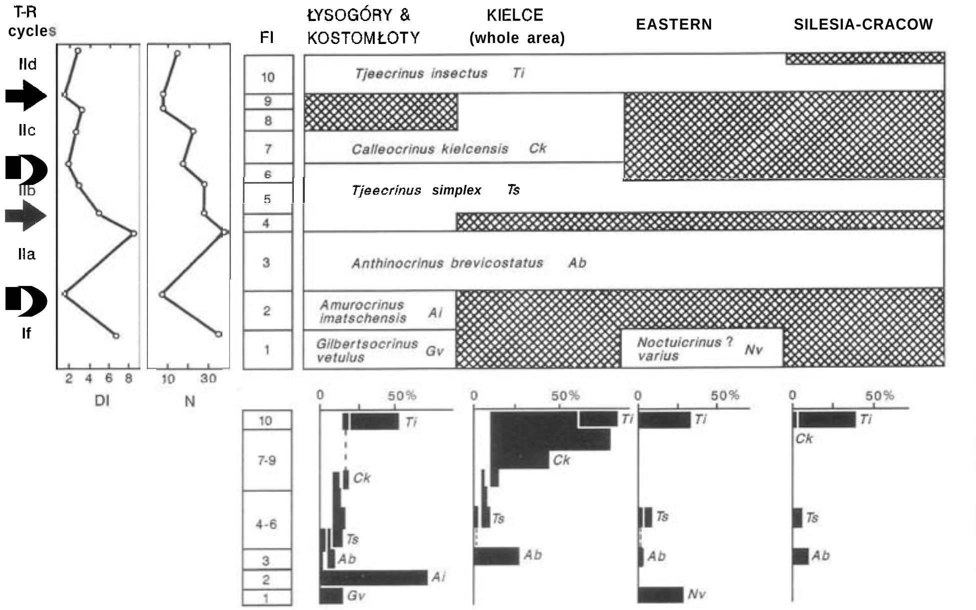


Fig. 23. Givetian-Frasnian crinoid successions based on substantial faunal changes and relative frequencies of the most representative species. FI – faunal intervals; DI – diversity index: N – number of taxa: T-R cycles of Johnson *et al.* 1985.

Therefore, the eustatic events were principally responsible for the changeovers in the crinoid habitats and corresponding alternations in the taxonomic composition of the faunas. This is the basis for the recognition of six-step crinoid succession in the Givetian to Frasnian sequence of southern Poland (Fig. 23).

(1) The oldest documented, diverse crinoid assemblages were introduced with the latest Eifelian to early Givetian T-R cycle If. Among 32 taxa, only four are common for the Eysogory and Kielce faunas, but they probably occur in the Early Eifelian 'Dąbrowa Limestone'. The most characteristic are the most numerous within and limited to FI 1, i.e. Gilbertsocrinus *vetulus* for the Łysogóry Region (Głuchowski 1981a) and Noctuicrinus? uarius for the Eastern Region.

(2) A peculiar fauna characterizes the regressive portion of the T-R cycle If. Its low diversity was caused by extensive previous local extinctions combined with only two biogeographically new taxa, including the most abundant Amurocrinus *imatschensis* (Głuchowski 1981a). The adverse tendency in the benthic biotope was probably connected with a rapid supply of clastics from an eastern source area (see Kłossowski 1985).

(3) Prominent diversity rise, typical of the FI 3, reflected the late Givetian transgressive event IIa. Crinoids again appeared in the southern areas of the carbonate platform. Among four recognized assemblages, the richest one thrived in the Kostomłoty basin. Five of 37 taxa are in common for all

the assemblages, but of them only *Anthinocrinus brevicostutus* is noted for first time.

(4) A remarkable faunal rebuilding, coupled with a decrease in diversity, in FI 4–6, was a response of crinoids to the T-R cycle IIb. During the period twenty six taxa disappeared probably in result of extinction (see Ebert 1992), while only eight ones entered the assemblages. The facies and faunal changes were already initiated by the deepening event in the K. *disparilis* Chrone in the Kostomloty area (FI 4), and with some delay (see also Racki & Bultynck in preparation) were manifested in a widespread drowning of south-lying shelf areas (FI 5). The number of crinoid assemblages diminished to two during the regressive development, and only three taxa were widely distributed in all the regions studied, including the newly appeared *Tjeecrinus simplex* (Gluchowski 1981a).

(5) A fluctuating diversity trend is a marked feature for five Frasnian crinoid assemblages-(FI7–9) associated with the T-R cycle IIc. In the whole interval sixteen taxa disappeared, but ten were newly introduced, including the typical reef-related forms, and among them numerous *Calleocrinus kielcensis*.

(6) Renewed diversification of the crinoids (FI 10) was stimulated by late Frasnian events, especially the prominent onlap IId. The faunal turnover is visible in the level-bottom assemblages of both the Holy Cross Mountains and Silesia-Cracow areas due to the repeated domination of *Schyschcatocrinus delicatus* and the appearance of *Tjeecrinus insectus*. However, the changes were insignificant in reef-dwelling faunas, where the participation of *T. insectus* is of little importance.

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Streszczenie

Na podstawie kolekcji pochodzqcych z 40 stanowisk opisano faunę liliowcow z żywetu i franu Gor Świętokrzyskich i regionu śląsko-krakowskiego. Sposrod 70 wyróżnionych taksonow tylko 9 zidentyfikowano w oparciu o kielichy, a **13** innych reprezentowanych jedynie przez fragmenty lodyg przypisano do rodzajow uprzednio zdefiniowanych kielichami. Pozostale typy lodyg, prawdopodobnie reprezentujące odrębne gatunki, sklasyfikowano w obrębie sztucznych jednostek kategorii ponadgatunkowych. Wsrod nich opisano **13** nowych gatunkow: *Anthinocrinus brevicostatus* sp. n., *Asperocrinus brevispinosus* sp. n., *Calleocrinus bicostatus* sp. n., *Calleocrinus kielcensis* sp. n., *Exaesiodiscus compositus* sp. n., *Kasachstanocrinus tenuis* sp. n., *Laudonomphalus pinguicostatus* sp. n., *Noctuicrinus? varius* sp. n., *Ricebocrinus parvus* sp. n., *Schyschcatocrinus delicatus* sp. n., *Schyschcatocrinus multiformis* sp. n., *Stenocrinus raricostatus* sp. n. i *Urushicrinus perbellus* sp. n.

Fauna liliowcowa reprezentowana jest przez **14** zespolow liliowcowych wyróżnionych na podstawie analizy podobienstw taksonomicznych 60 prob i określonych nazwami dominujqcych taksonow: *Anthinocrinus* (Ab), *Amurocrinus* (Ai), *Calleocrinus* (Ck), *Glyphidocrinus* (G), *Calleocrinus-Schyschcatocrinus* (CkSm), *Kasachstanocrinus-Marettocrinus* (KtMa), *Marettocrinus-Facetocrinus* (MkFq), *Schyschcatocrinus-Floricrinus* (SdF), *Schyschcatocrinus-Stenocrinus* (SdSr), *Schyschcatocrinus-Tjeecrinus* (SdTi), *Schyschcatocrinus* (Smd), *Schyschcatocrinus-Marettocrinus* (SmMk), *Stenocrinus-Noctuicrinus?* (SrNv) i Tantalocrinus-Gilbertsocrinus (TsGv).

Paleogeograficzne rozprzestrzenienie i skład taksonomiczny zespolow liliowcowych odzwierciedlają zróżnicowanie srodowisk liliowcowych. Mniejsze taksonomiczne zroznicowanie faun liliowcowych w południowej części obszaru świętokrzyskiego, wskazuje na mniej korzystne dla liliowcow warunki srodowiskowe w obrębie plafformy stromatoporoidowo-koralowcowej, zwlaszcza w fazie platformowej rozwoju facjalnego. W czasie fazy rafowej następuje zmiana charakteru i pewne ujednolicenie sldadu taksonomicznego faun liliowcowych na całym obszarze. Jednak ich zróżnicowanie taksonomiczne jest generalnie mniejsze niż w fazie plafformowej co Swiadczy o niekorzystnych zmianach w srodowiskach liliowcowych.

Istotne zmiany taksonomicznego zroznicowania faun liliowcowych powodowane zasadniczymi zmianami środowiskowymi pozostajq w ścisłym związku z ponadregionalnymi wydarzeniami eustatycznymi. Wsrod liliowcow z żywetu i franu obszaru świętokrzyskiego zaznacza się następstwo sześciu faun liliowcowych, ktorych rozwoj wyraźnie wiąże się z kolejnymi cyklami transgresywno-regresywnymi: G. *vetulus/N. ?varius* (If – faza transgresywna), A. *imatschensis* (If – faza regresywna), A. *brevicostatus* (IIa), *T. simplex* (IIb), *C. .kielcensis* (IIc) i *T. insectus* (IId).