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The Lower Muschelkalk crinoids from Raciborowice, North-Sudetic Basin, SW Poland

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Five Middle Triassic crinoid taxa: *Eckicrinus radiatus* (Schauroth, 1859), *Holocrinus acutangulus* (Meyer, 1847), *H. dubius* (Goldfuss, 1831), *Dadocrinus* sp. and Encrinidae gen. et sp. indet., from the North-Sudetic Basin, are described. The occurrence of *Eckicrinus radiatus* (Schauroth) is reported in the area for the first time. Based on the stratigraphic distribution of the crinoids, the ranges of three crinoid zones (*Dadocrinus* Zone, *acutangulus* Zone and *dubius* Zone) have been constrained. A modified correlation between the Lower Muschelkalk deposits of the North-Sudetic Basin, Upper Silesia and the Holy Cross Mountains is proposed.

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Key words: North-Sudetic Basin, Triassic, Muschelkalk, crinoids.

INTRODUCTION

Middle Triassic crinoids from the North-Sudetic Basin have not, to date, been studied in detail, and the few references to them not always have been taxonomically and/or stratigraphically correct. The first references to the Lower Muschelkalk crinoids from the North-Sudetic Basin can be found in Nötling (1880), who noted *Encrinus gracilis* Buch (= *Dadocrinus gracilis*) and *Entrochus dubius* Goldfuss (= *Holocrinus dubius*). Nötling also recorded the presence of encrinids, referring them incorrectly to *Encrinus liliiformis* Lamarck, as did subsequently Milewicz and Wójcik (1973), Leśniak (1978) and Senkowiczowa (1979). This species probably occurs in southern Poland but first appears in the Upper Muschelkalk (see Salamon *et al*., 2003). More detailed data on crinoids from the village of Raciborowice Górne were given by Hagdorn and Głuchowski (1993). They noted dadocrinids and *Holocrinus acutangulus* (Meyer) from unit A of Szulc (1991) (= unit B *sensu* Chrząstek, 2002*a*) and *H. dubius* (Goldfuss) from units C and D of Szulc (1991) (= units D and E *sensu* Chrząstek, 2002*a*). These observations were extended by later research (Chrząstek, 2002*a*, table 1), who reported, within units she distinguished, *Dadocrinus* (in unit B), *Holocrinus acutangulus* (Meyer) (in units B and C), *H. dubius* (Goldfuss) (in units D and E) and encrinids (in units C–E). Moreover, Chrząstek (1995, 2002*a*) noted that *H. dubius* (Goldfuss) and encrinids also occurred at Jerzmanice. This has essentially been confirmed by this study, with additionally *Eckicrinus radiatus* (Schauroth) having been documented for the first time, from units C–E. Recently, Salamon *et al*. (2003) reported *Holocrinus acutangulus* (Meyer) from the units C and D *sensu* Chrząstek (2002*a*), though detailed analysis of their material shows that crinoid columnals from unit D belong only to *H. dubius* (Goldfuss). Chrząstek (2002*b*, 2003) also mentioned the presence of *H. acutangulus* (Meyer) and *H. dubius* (Goldfuss) in unit D from Raciborowice quarry, though this observation may be questioned since these two holocrinid species have never previously been seen to co-occur.

GEOLOGICAL SETTING

The North-Sudetic Basin is bordered to the north-east by the Fore-Sudetic Block, and to the south-west by the Karkonosze–Izera crystalline massif. At its base, Eocambrian-Lower Carboniferous metamorphic rocks of the Kaczawa Complex occur. The overlying deposits, consisting mainly of sedimentary

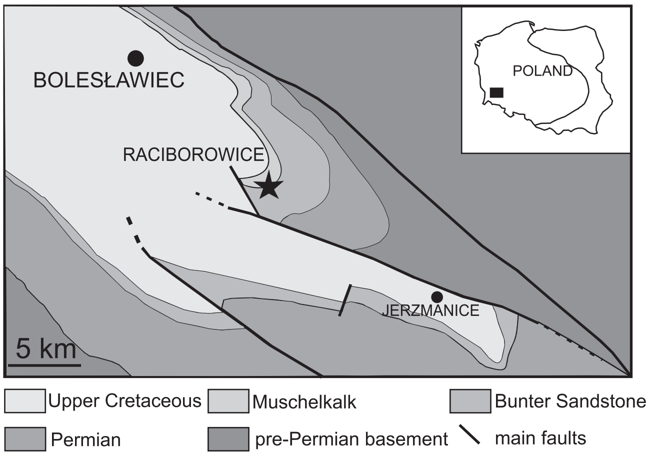

Fig. 1. Geological sketch-map of the North-Sudetic Basin (without Cenozoic) (after Salamon *et al.*, 2003, modified)

rocks, are Late Carboniferous-Triassic and Late Cretaceous-Cenozoic in age (see Chrząstek, 2002*a*). The Lower Triassic is represented here by terrigenous deposits of the Bunter Sandstone, including Röt carbonates. Overlying calcareous-marly deposits of the Lower Muschelkalk are exposed at the surface only in the northern and eastern parts of the North-Sudetic Basin. Younger, Mid-Upper Triasssic deposits are known only from boreholes (see Chrząstek, 2002*a*). The most complete section of the Lower Muschelkalk occurs in Raciborowice Górne (guarry no. 1; see Leśniak, 1978; Chrząstek, 2002*a*), which is about 13 km to the south-east from Bolesławiec (Fig. 1). Deposits of the Lower Muschelkalk, outcropping in the Raciborowice area, have been the subject of many studies since the end of the 19th century (see Chrząstek, 2002*a*). A detailed stratigraphic analysis of this region was made by Leśniak (1978), who divided the entire Lower Muschelkalk into seven lithostratigraphic units (complexes VII–XIII). Szulc (1991) subsequently made a generalized lithostratigraphic subdivision (into units A–D) and suggested a correlation with their Upper Silesian equivalents. In his opinion, the higher part of unit A together with unit B correspond to the Gogolin Beds, unit C corresponds to the Górażdże Formation, and unit D to the *Terebratula* Beds (= the Dziewkowice Formation). Chrząstek (2002*a*) provided a similar analysis, and, referring to the concept of her predecessor, distinguished here units B–E that are equivalent to units A–D of Szulc (1991). However, unit A *sensu* Chrząstek (2002*a*), not exposed in Raciborowice quarry, was documented by her in Jerzmanice quarry and regarded as the oldest member of the Lower Muschelkalk. Moreover, she considered that her units B and C are equivalent of the Gogolin Beds, unit D corresponding to the Górażdże Formation, and unit E corresponding to the Dziewkowice Formation, while the unit A was recognized as a probable equivalent of the Błotnica Beds of Upper Silesia.

MATERIAL

The crinoid material examined was collected in Raciborowice quarry during fieldwork in 2002. It is represented exclusively by separate skeleton ossicles (mostly stem parts). The collection comprises a few hundred rather poorly preserved pluricolumnals, columnals, brachials and calyx plates obtained by washing the marly samples, and from weathered limestone slab surfaces. The photographs were taken using a *Philips ESEM XL 30* microscope. The material is stored at the Department of Palaeontology and Biostratigraphy of the University of Silesia in Sosnowiec (Catalogue Number GIUS-7-2328).

TAXONOMIC REVIEW OF THE FAUNA

Order **Millericrinida** Sieverts-Doreck, 1952
Family **Dadocrinidae** Lowenstam, 1942
Dadocrinus sp.
(Fig. 2A–L)

The low and subpentagonal to subcircular columnals come from the proxistele to mesistele, whereas markedly rounded and higher ones represent the dististele. Towards the distal end of the stem their pentaradial symmetry gradually disappears. The lateral side of the columnals is flat or convex. The lumen is relatively large, circular or slightly pentagonal and locally surrounded by a pentagonal, smooth or denticulate perilumen. The crenulae are thick, short in proxistele to long in dististele. The discoidal holdfasts fixing the stems to a solid substratum have a more or less regular outline.

The genus is represented in Upper Silesia by four species (morphotypes?). Three of them are ten-armed: *Dadocrinus gracilis* (Buch), *D. kunischi* Wachsmuth et Springer and *D. grundeyi* Langenhan; and one is a still unnamed five-armed form (Głuchowski, 1986; Hagdorn and Głuchowski, 1993). The taxonomic diagnoses of all the species comprise their cup and arm structures, and distinction-based solely on stems or dissociated cup plates is not possible (see Lefeld, 1958; Głuchowski, 1986; Hagdorn and Głuchowski, 1993; Hagdorn, 1996). The genus *Dadocrinus* occurs in the Lower Anisian of southern Poland and eastern Germany and outside the Germanic Basin the genus is reported from the Austroalpine and Dinarid regions (Lefeld, 1958; Kristan-Tollmann and Tollmann, 1967; Głuchowski, 1986; Hagdorn and Głuchowski, 1993; Hagdorn *et al.*, 1996, 1997; Salamon, 2003). According to Kristan-Tollmann (1986) its range may extend over the western Tethys. Recently, Eagle (2003) reported *Dadocrinus gracilis* (Buch) from New Zealand, but the taxonomic status of the figured specimen seems doubtful.

Order **Isocrinida** Sieverts-Doreck, 1952
Family **Holocrinidae** Jaekel, 1918
Holocrinus acutangulus (Meyer, 1847)
(Fig. 3A–E)

The columnals described are stellate to pentagonal with a small, circular lumen. The articular facet is bordered by infrequent, thick marginal crenulae. The adradial crenulae are weakly developed in the form of nodules. Petal floors are nar-

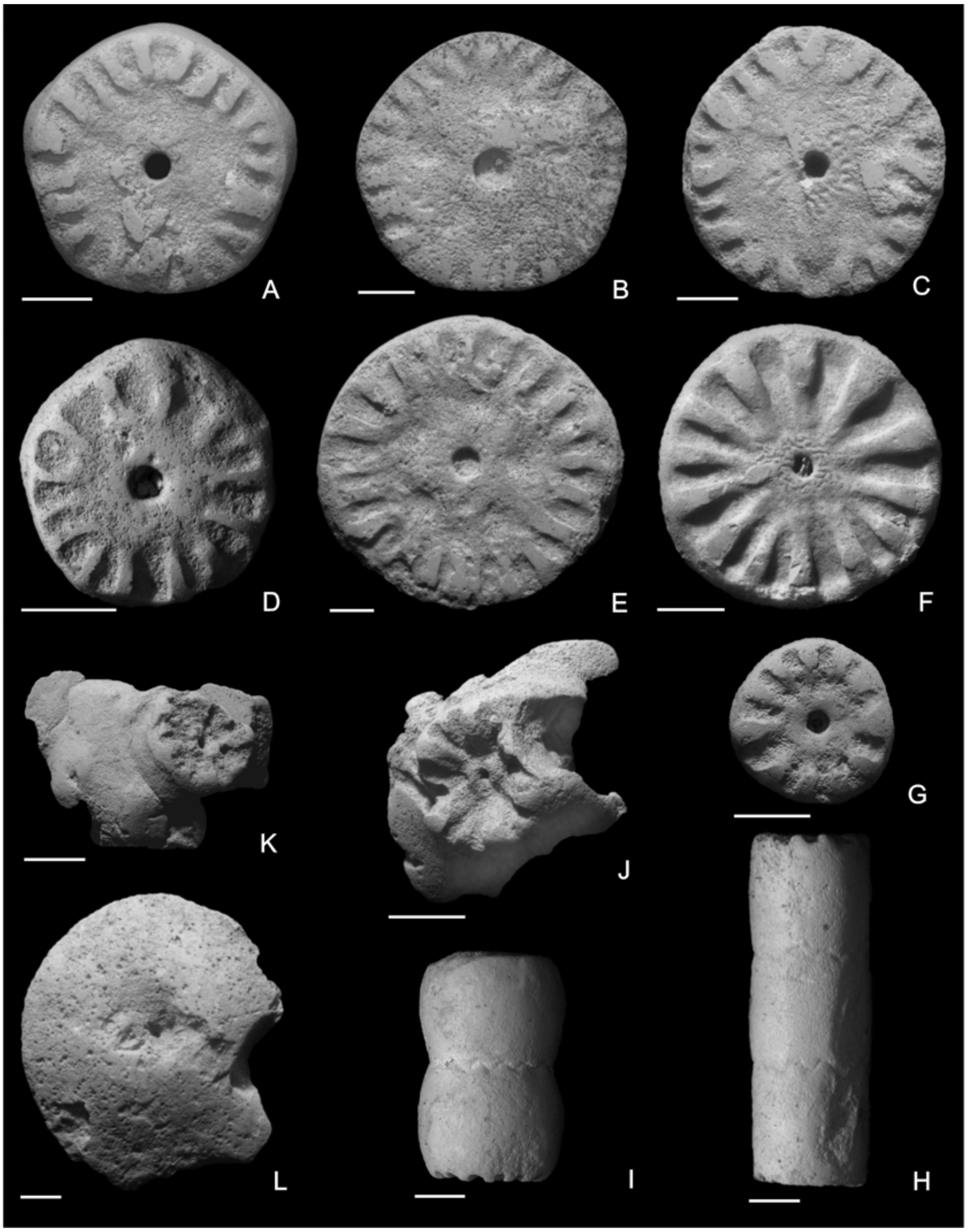

Fig. 2. *Dadocrinus* sp. from Raciborowice quarry

A — proximal columnal (unit B/6); **B**, **C** — medial columnal (unit B/6); **D** — medial columnal (unit B/8); **E**, **F**, **I** — distal columnal (unit B/6); **G** — distal columnal (unit B/1); **H** — distal pluricolumnal (unit B/6); **J**, **K**, **L** — discoid holdfast (unit B/6); scale bars — 0.5 mm

row, lanceolate. The nodals bear five relatively large and oval cirrus scars. The species occurs in the Lower Anisian-Pelsonian of southern Poland, eastern and southwestern Germany and outside the Germanic Basin in the Austroalpine region (Głuchowski, 1986; Hagdorn, 1986; Hagdorn and Głuchowski, 1993; Hagdorn *et al*., 1997; Salamon, 2003).

Holocrinus dubius (Goldfuss, 1831)
(Fig. 3F–J)

The columnals described are pentagonal to subpentagonal or subcircular with a very small, circular lumen. The articular

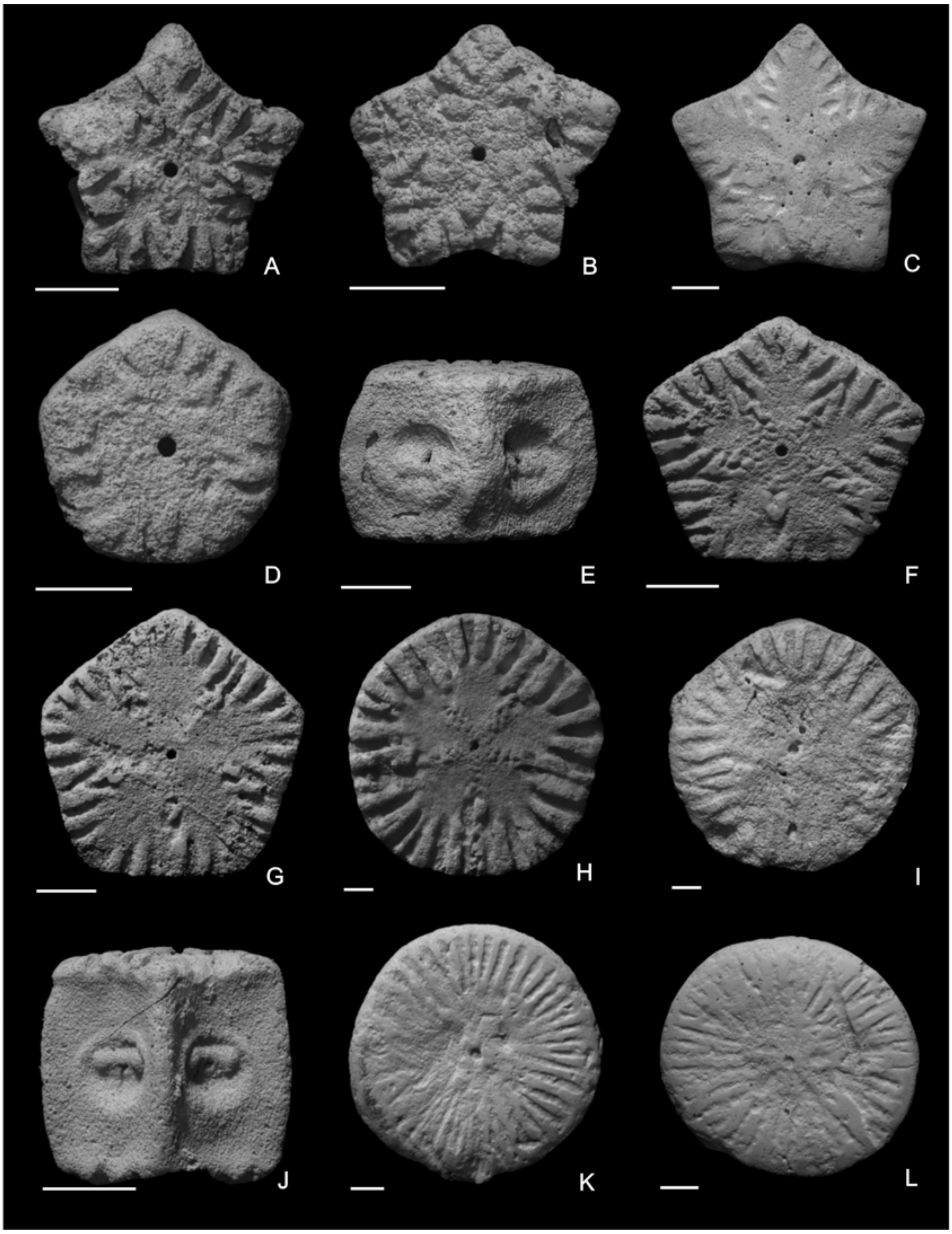

Fig. 3. Holocrinidae from Raciborowice quarry

A–**E** — *Holocrinus acutangulus* (Meyer): **A**, **E** — nodal (unit B/4), **B**, **D** — internodal (unit B/4), **C** — internodal (unit B/6); **F**–**J** — *Holocrinus dubius* (Goldfuss): **F** — internodal (unit D/21), **G**, **H** — internodal (unit D/25), **I** — internodal (unit E/26), **J** — nodal (unit D/22); **K**, **L** —*Eckicrinus radiatus* (Schauroth): **K** — internodal (unit C/20), **L** — internodal (unit D/25); scale bars — 0.5 mm

facet is covered with moderate thick marginal and denticulate adradial crenulae arranged in five bands. Petal floors are well developed, wide, lanceolate to pyriform. The nodals bear five relatively small and oval cirrus scars. The species occurs in the Pelsonian of southern Poland and southwestern Germany and outside the Germanic Basin in the Pelsonian-Lower Illyrian of the Austroalpine region (Hagdorn, 1986; Hagdorn and Głuchowski, 1993; Hagdorn *et al*., 1997; Salamon, 2003) and Caucasus (Klikushin, 1982).

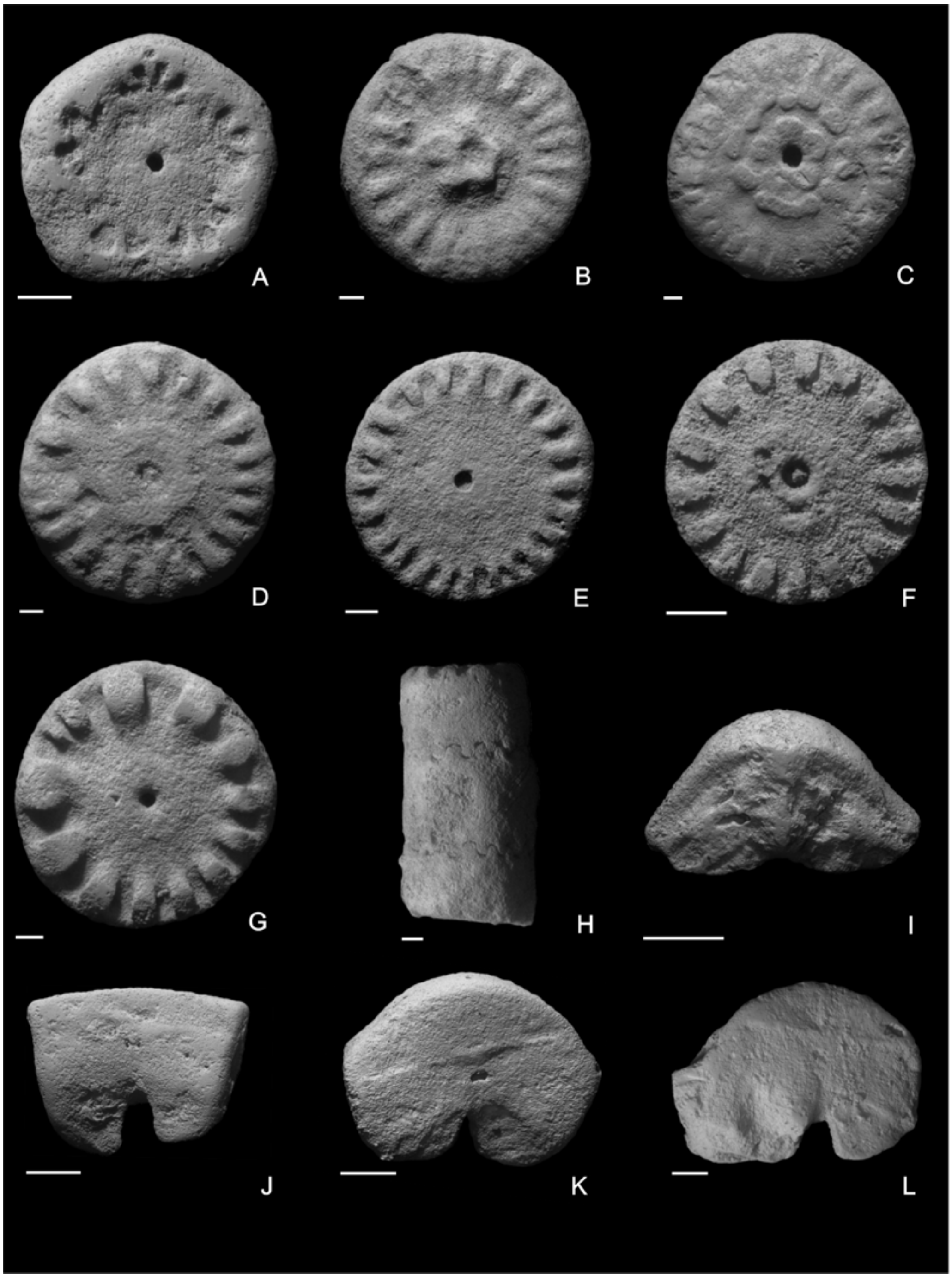

Fig. 4. Encrinidae gen. et sp. indet. from Raciborowice quarry

A — proximal nodal (unit C/20); **B**, **C** — medial columnal (unit D/21); **D**, **E**, **G** — distal columnal (unit C/20); **F** — distal columnal (unit D/24); **H** — distal pluricolumnal (unit C/20); **I** — axillary plate (unit C/14); **J** — proximal brachial plate (unit C/16); **K**, **L** — distal brachial plate (unit C/16); scale bars — 0.5 mm

Eckicrinus radiatus (Schauroth, 1859)
(Fig. 3K and L)

The columnals described are low and circular. The lumen is extremely narrow and circular. The articular facet is flat, bordered by numerous and long marginal crenulae. The adradial crenulae are arranged in five small bands composed of minute tubercles. The petal floors are pyriform, very small and poorly visible. The nodals bear five very small and round cirrus scars. The species occurs in the Pelsonian-Lower Illyrian of southern Poland and outside the Germanic Basin in the Austroalpine and Dinarid regions (Głuchowski, 1986; Hagdorn, 1986; Hagdorn and Głuchowski, 1993; Hagdorn *et al*., 1996, 1997; Salamon, 2003), as well as in eastern Siberia (Klikushin, 1982).

Order **Encrinida** Matsumoto, 1929
Family **Encrinidae** Dujardin et Hupé, 1862
Encrinidae gen. et sp. indet.
(Fig. 4A–L)

The columnals from the proximal part of the stem are subpentagonal and low. The lateral sides of internodals are straight and the latera of nodals are strongly convex. The articulum is distinctly pentalobate and bordered by thick and short crenulae. The columnals from the medial and distal parts of the stem are circular and relatively higher, and their lateral side is straight or slightly convex. Their articulum is bordered by very thick and short crenulae. All the columnals have a relatively large and rounded lumen, in some cases surrounded by a more or less distinct pentalobate to pentagonal and often ornamented perilumen. The axillary brachials have a well developed distal muscular facet, a flat zygosynostosial proximal facet, and their dorsal side is convex. The proximal brachials are trapezoidal with a smooth dorsal side. The distal brachials are wedge-shaped and semicircular, also with a smooth dorsal side.

All these morphological features are characteristic of some species belonging to *Encrinus*, *Chelocrinus* and *Carnallicrinus*. However, since the structure of calyces and the number of arms are unknown, attribution to any of these genera is impossible (see Głuchowski and Boczarowski, 1986; Hagdorn and Głuchowski, 1993; Hagdorn *et al*., 1996). Because all examined brachial plates have smooth dorsal sides they cannot belong to *Encrinus aculeatus* Meyer or to *E. spinosus* Michael, known from Upper Silesia. Since all of the encrinid material examined did not contain columnals with cirrus scars, the encrinid remains may belong to *Encrinus robustus* Assmann or *Carnallicrinus carnalli* (Beyrich). However, complete specimens of the latter species, older than Pelsonian in age, have not been found yet.

SUCCESSION OF CRINOID FAUNAS

Crinoids were found in twenty-six samples taken from the entire succession of the Lower Muschelkalk lithostratigraphic units (B–E) *sensu* Chrząstek (2002*a*) distinguished in Raciborowice quarry (Fig. 5). Their succession comprises three crinoid zones: the *Dadocrinus* Zone, the *acutangulus* Zone and the *dubius* Zone, documented for the first time in the North-Sudetic Basin by Chrząstek (2002*a*). However, their ranges were distinguished incorrectly and not in accord with the original definition of Hagdorn and Głuchowski (1993) in the Upper Silesia area.

DADOCRINUS ZONE

The base of this zone is marked by the first occurrence of dadocrinids, and its top by their disappearance (range biozone); it extends only through unit B (not in unit B and in the lower part of unit C as stated by Chrząstek, 2002*a*). Originally, the zone was defined as being

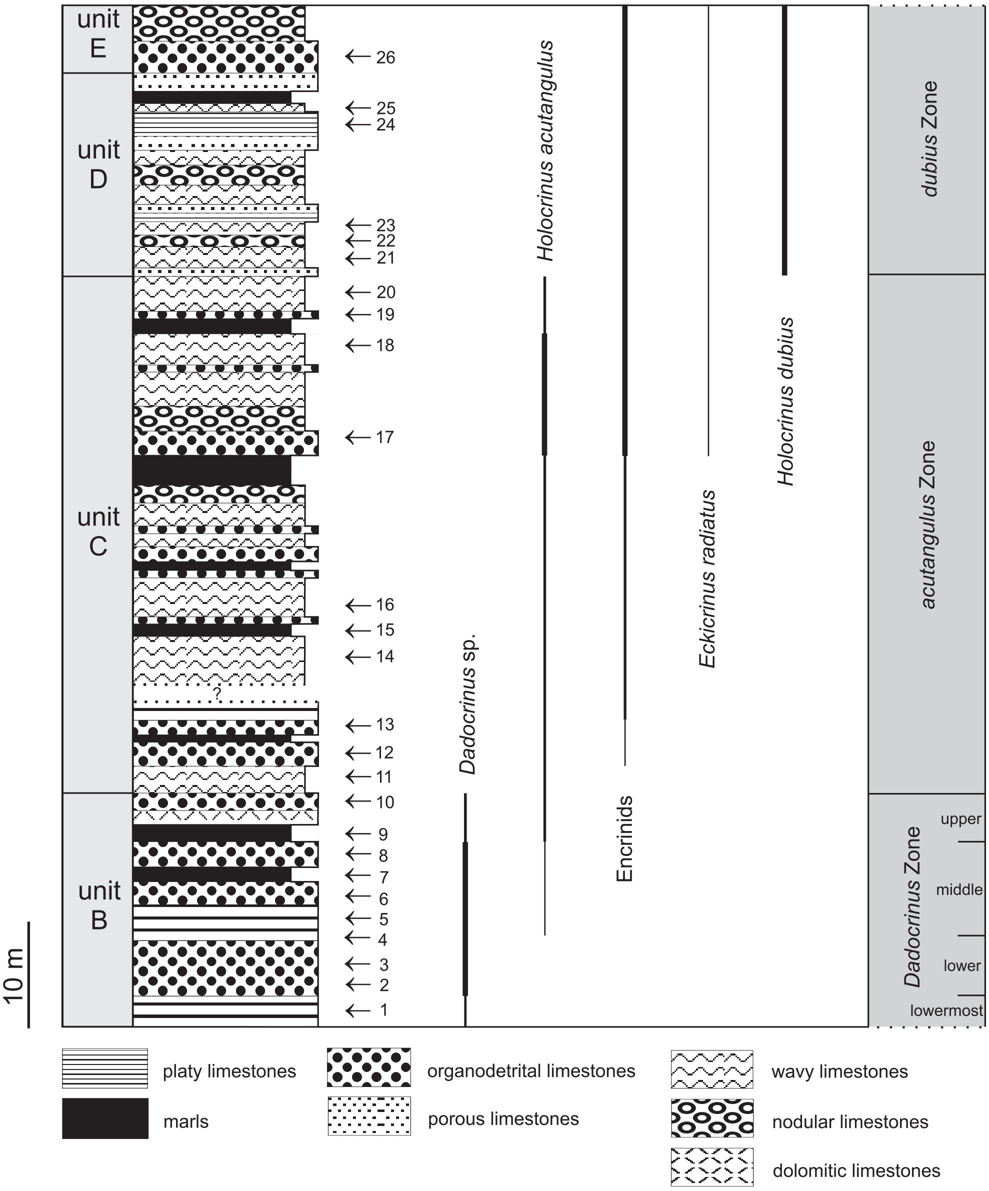

Fig. 5. Stratigraphic distribution of crinoids in the Lower Muschelkalk from Raciborowice quarry (lithostratigraphic units B–E after Chrząstek, 2002*a*; crinoid zones as defined in the present paper)

1–26 — numbers of samples

divisible into three (Hagdorn and Głuchowski, 1993), and subsequently into four (Salamon, 2003). Dadocrinid columnals initially appear in small numbers at the base of unit B (lowermost part of the zone). Then, their frequency increases substantially (lower part of the zone). In the middle part of unit B *Holocrinus acutangulus* (Meyer) appears in small numbers (middle part of the zone), which become more frequent towards the top of unit B (upper part of the zone). Unit B is developed as organodetrital limestones with intraclasts, marly and dolomitic limestones and marls and contains a fairly rich accompanying fauna. This comprises mainly bivalves, gastropods, brachiopods, as well as foraminifers, reptile remains and ichnofossils (see Chrząstek, 2002*a*).

ACUTANGULUS ZONE

The base of this zone is marked by the disappearance of dadocrinids, and its top by the first occurrence of *Holocrinus dubius* (Goldfuss) (partial range biozone); it extends through all of unit C (not through the higher part of unit C and the lower part of unit D as stated by Chrząstek, 2002*a*). Apart from the index species *Holocrinus acutangulus* (Meyer), a few ossicles of *Eckicrinus radiatus* (Schauroth), appearing in the upper part of unit C, and encrinids that appeared in the lowest part of this unit are present here. From the *Punctospirella fragilis* Horizon (sample 17) up to the top of the section, crinoids occur in abundance. Unit C is developed as marly limestones, marls and organodetrital limestones with intraclasts. Very rich accompanying faunal assemblages have been reported here, consisting mainly of bivalves, brachiopods and gastropods, and to a lesser degree of ammonoids, foraminifers, phyllopods, fish and reptile remains and ichnofossils (see Kaim and Niedźwiedzki, 1999; Chrząstek, 2002*a*), as well as conodonts (see Kędzierski, 1996).

DUBIUS ZONE

The base of this zone is marked by the first occurrence of *Holocrinus dubius* (Goldfuss), and its top by appearance of *Silesiacrinus silesiacus* (Beyrich) (partial range biozone); it extends through the two youngest units D and E (not only the upper part of unit D and in unit E as stated by Chrząstek, 2002*a*). The index species and encrinids are very numerous here, but *Eckicrinus radiatus* (Schauroth) is still rare. However, *Silesiacrinus silesiacus* (Beyrich) has not been reported so far in the North-Sudetic Basin, so it is likely that the Lower Muschelkalk deposits from Raciborowice quarry do not comprise the upper, or at least the uppermost part of the *dubius* Zone. Another possible explanation is that silesiacrinids do not extend their geographical range as far to the west. Unit D is developed as marly, organodetrital, oncolite and porous limestones, while unit E comprises organodetrital and marly limestones. In both these units the accompanying fauna is much less diverse and is represented mainly by brachiopods, bivalves and foraminifers (see Chrząstek, 2002*a*), whereas conodonts are much more numerous here (see Kędzierski, 1996).

STRATIGRAPHIC IMPLICATIONS

Taxonomic assessment of the Lower Anisian-Pelsonian crinoid faunas from the eastern part of the Germanic Basin, and their succession, enable correlation of lithostratigraphic units of the North-Sudetic Basin with their Upper Silesia and the Holy Cross Mountains equivalents (Fig. 6).

According to Chrząstek (2002*a*) the lowermost part of the Muschelkalk in the North-Sudetic Basin consists of yellowish dolomitic limestones of unit A exposed in Jerzmanice quarry. These are devoid of crinoids and contain only sparse fish remains. Their stratigraphic position is not fully clear. Chrząstek (2002*a*) suggested that unit A may correspond to the basal part of complex VII *sensu* Leśniak (1978), with unit B corresponding to the upper part of this complex. However, detailed analysis of the lithology and thickness of the Lower Muschelkalk deposits in the neighbourhood of Raciborowice Górne indicates that complex VII corresponds almost entirely to unit B. Thus, unit A is rather an equivalent of the upper dolomitic part of complex VI *sensu* Leśniak (1978) belonging to the Röt. The Röt/Muschelkalk boundary is distinctly diachronous over the area of the Germanic Basin and often its position is not clear (see Bodzioch, 2000). Traditionally, in the area of Upper Silesia and the Holy Cross Mountains the boundary is marked by the mass(!) appearance of crinoids (*Dadocrinus*), according

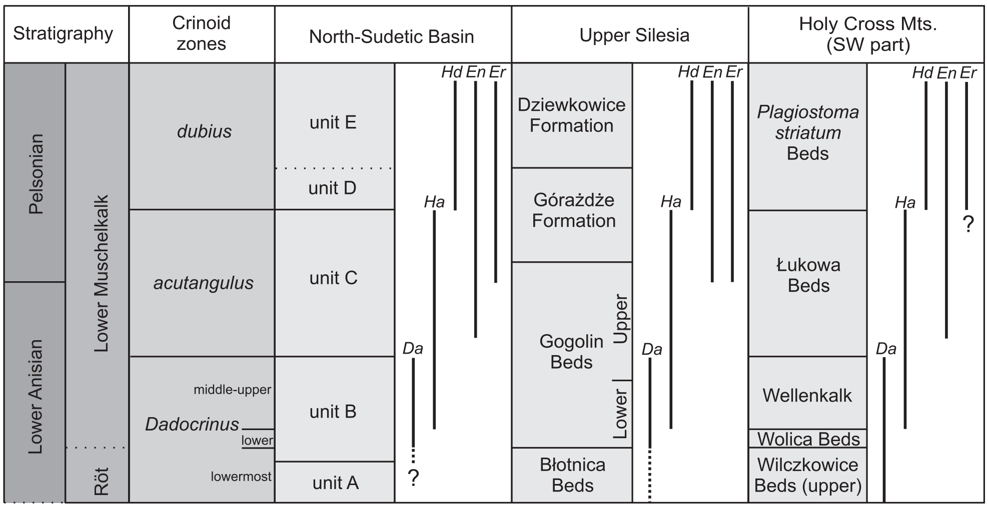

Fig. 6. Stratigraphic correlation scheme for the Lower Anisian-Pelsonian deposits of southern Poland, based on crinoid zonation

Da — *Dadocrinus* sp., *Ha* — *Holocrinus acutangulus* (Meyer), *Hd* — *Holocrinus dubius* (Goldfuss), *Er* — *Eckicrinus radiatus* (Schauroth), *En* — encrinids; very low frequency marked by dotted lines; lithostratigraphy after Assmann (1944), Senkowiczowa *et al*. (1973), Kotlicki (1974), Niedźwiedzki (2000) and Chrząstek (2002*a*) to the concept of Assmann (1944). A similar criterion for marking this boundary over the area of the North-Sudetic Basin and the Fore-Sudetic Monocline was applied by Senkowiczowa (1992). Thus, the Röt/Muschelkalk boundary in the region of Raciborowice would be placed at the base of the thick-bedded organodetrital limestones with numerous crinoids, i.e. about 2 m above the base of unit B (= base of complex VII of Leśniak, 1978). Chrząstek (2002*a*) suggested that unit A from the North-Sudetic Basin corresponds to the Muschelkalk Błotnica Beds defined by Kotlicki (1974) in Upper Silesia, which seems to be correct. The calcareous deposits of the Błotnica Beds are also poor in fossils, but occasionally a few crinoid ossicles (*Dadocrinus*?) have been reported here (Kotlicki, 1980). Only at the base of the Gogolin Beds do crinoids of the genus *Dadocrinus* appear in abundance. According to Senkowiczowa (1965, 1980), lithological equivalents of the Błotnica Beds (= Rötkalk of Assmann, 1933, 1944; = "cavernous limestone" or *Myophoria vulgaris* Beds of Siedlecki, 1952) correspond to the upper part of the Röt Wilczkowice Beds documented in the Holy Cross Mountains, the Carpathian Foreland and Fore-Sudetic Monocline areas. Crinoid ossicles referable to *Dadocrinus* are not common in the Wilczkowice Beds from the Holy Cross Mountains, and their mass occurrence is noted only in the Wolica Beds (Salamon, 2003). The question of the Olenekian/Anisian boundary in the Germanic Basin is also controversial. Palaeontological data indicate that at least a part of the Röt deposits is Anisian in age. According to Visscher *et al*. (1993) and Kozur (1998) the entire Röt succession in the Germanic Basin should be regarded as Anisian in age. In the Holy Cross Mountains and Upper Silesia, the Olenekian/Anisian boundary goes through the uppermost part of the Röt (Trammer, 1975; Zawidzka, 1975; Trammer and Zawidzka, 1976). However, the interpretation of magnetostratigraphic data given recently by Nawrocki and Szulc (2000*a*, *b*) suggests different correlation. These authors considered the entire Röt together with the lowest part of the Lower Muschelkalk from these areas to be Olenekian in age. Results of previous biostratigraphic and palaeobiogeographic studies, that define among others, routes of immigration of an "Alpine fauna" into the Germanic Basin, are not consistent with this interpretation. For instance, *Dadocrinus* is not known outside the Germanic Basin from any localities older than Anisian in age.

The lowest part of the *Dadocrinus* Zone with infrequent dadocrinids comprises the highest part of the Wilczkowice Beds in the Holy Cross Mountains (Salamon, 2003), and probably the Błotnica Beds in the Upper Silesia area. Whereas, in the North-Sudetic Basin, this subzone would comprise the crinoid-free unit A and the lowest part (~ 2 m) of unit B, poor in dadocrinid ossicles. However, the relatively higher frequency of dadocrinids in the Wilczkowice Beds from the Holy Cross Mountains seems confirm the gradual expansion of their geographical range at that time from the east to the west. The western range boundary of *Dadocrinus* within the Germanic Basin is Brandenburg in eastern Germany (Hagdorn and Głuchowski, 1993).

The lower part of the *Dadocrinus* Zone, with abundant dadocrinids, comprises the Wolica Beds in the Holy Cross Mountains (Salamon, 2003), and the lower part of the Lower Gogolin Beds (up to the top of the *Pecten* and *Dadocrinus* Limestones) in Upper Silesia (Hagdorn and Głuchowski, 1993), whereas in the North-Sudetic Basin this subzone comprises the lower part of unit B.

The middle and upper parts of the *Dadocrinus* Zone with dadocrinids and the co-occurrence of *Holocrinus acutangulus* (Meyer), include the Wellenkalk in the Holy Cross Mountains (Salamon, 2003), the upper part of the Lower Gogolin Beds and the lower part of the Upper Gogolin Beds (up to the Inter-Wellenkalk Limestones) in Upper Silesia (Hagdorn and Głuchowski, 1993), and the upper part of unit B in the North-Sudetic Basin.

The *acutangulus* Zone represents the upper part of the Lower Anisian and the lower part of the Pelsonian. The conodont fauna indicates that the Lower Anisian/Pelsonian boundary in Upper Silesia runs within a higher part of the Upper Gogolin Beds, and in the Holy Cross Mountains within a higher part of the Łukowa Beds (Trammer and Zawidzka, 1976). The analysis of conodont assemblages from Raciborowice quarry given by Kędzierski (1996) is ambiguous and shows only that the Lower Anisian/Pelsonian boundary runs in the interval comprising the higher part of unit C and lower part of unit D. Two maximum peaks of frequency of massive conodonts are evident here. Because of the lack of diagnostic species, we have placed the boundary at the base of unit D, i.e. where the second assemblage of massive forms appears, indicating the peak of transgression. In the neighbouring area of Upper Silesia the peak of transgression took place in the late Pelsonian (the Dziewkowice Formation = the *Terebratula* Beds), while the first strong transgressive pulse is registered within the Upper Gogolin Beds (Szulc, 1993). So, it is likely that in the North-Sudetic Basin the Lower Anisian/Pelsonian boundary marks the appearance of the first assemblage of massive forms, documented by Kędzierski (1996) in the higher part of the unit C. Chrząstek (2002*a*) also seemed to support this interpretation, indicating the first trangressive pulse within the same part of the section (unit C, the *Punctospirella fragilis* Horizon). It must be stressed that the frequency of crinoids increases from the same level and *Eckicrinus radiatus* (Schauroth) appears, a species which is not reported from any localities older than Pelsonian in age. In the Holy Cross Mountains the *acutangulus* Zone comprises the Łukowa Beds (Salamon, 2003), in Upper Silesia the higher part of the Upper Gogolin Beds and (except for its uppermost part) the Górażdże Formation (Hagdorn and Głuchowski, 1993). By contrast, in the North-Sudetic Basin the zone would comprise all of unit C. It is also interesting that encrinids appear in the North-Sudetic Basin as early as in Lower Anisian times, as in the Holy Cross Mountains (see Salamon, 2003), whereas they appear in Upper Silesia only at the beginning of the Pelsonian (Hagdorn and Głuchowski, 1993).

The *dubius* Zone in the Holy Cross Mountains includes the *Plagiostoma striatum* Beds (Salamon, 2003), while in Upper Silesia it encompasses the top of the Górażdże Formation, the Dziewkowice Formation and the basal part of the Karchowice Beds (Hagdorn and Głuchowski, 1993). In the North-Sudetic Basin, the zone (without its uppermost part) comprises both units D and E. Unit D likely corresponds to the top part of the Górażdże Formation, and maybe even to part of the Dziewkowice Formation and the lower part of the

Plagiostoma striatum Beds. Unit E would correspond to the Dziewkowice Formation and the upper part of the *Plagiostoma striatum* Beds.

The correlation of the Lower Muschelkalk deposits in southern Poland, as given here, supports the concept of significant facies diachroneity which Trammer and Zawidzka (1976) suggested. The distribution of the lithologically similar facies of the Łukowa Beds in the Holy Cross Mountains and the Górażdże Formation in Upper Silesia, as well as of unit D in the North-Sudetic Basin, is strong evidence for this. The diachroneity may be associated with the tectonic, climatic and eustatic factors that controlled sedimentation in the Germanic Basin. It resulted particularly from the development of tectonic depressions (gates) proceeding from the east to the west, through which marine waters were exchanged between the western Tethys and its peripheral sea (Szulc, 1999, 2000).

CONCLUSIONS

We have described the Lower Muschelkalk crinoid fauna, including the ossicles of *Eckicrinus radiatus* (Schauroth), reported for the first time from the North-Sudetic Basin, and have constrained the ranges of three crinoid zones documented in this area by Chrząstek (2002*a*). This has enabled more precise time correlation and comparison of the lithostratigraphic units A–E *sensu* Chrząstek (2002*a*) with their Upper Silesian and Holy Cross Mountains equivalents. Thus, unit A and the lowermost part of unit B (lowest part of the *Dadocrinus* Zone) can be compared to the Błotnica Beds and the upper part of the Wilczkowice Beds. The remaining part of unit B (lower to upper parts of the *Dadocrinus* Zone) corresponds to the Lower Gogolin Beds and the lower part of the Upper Gogolin Beds, as well to the Wolica Beds and Wellenkalk. Unit C (*acutangulus* Zone) corresponds to the higher part of the Gogolin Beds and the Górażdże Formation (but not its highest part), as well to the Łukowa Beds. Units D and E (*dubius* Zone) correspond to the uppermost part of the Górażdże Formation and the Dziewkowice Formation, as well to the *Plagiostoma striatum* Beds.

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