GEOLOGICA CARPATHICA, APRIL 2006, 57, 2, 69–77

Triassic crinoids from the Tatra Mountains and their stratigraphic significance (Poland)

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(Manuscript received February 18, 2005; accepted in revised form October 6, 2005)

Abstract: Stratigraphically important crinoid species *Holocrinus acutangulus* (Meyer) and *Holocrinus dubius* (Goldfuss) have been found for the first time in the Tatras, and the occurrence of *Silesiacrinus silesiacus* (Beyrich) was clarified. The following crinoid Zones: *Dadocrinus*, *acutangulus*, *dubius* and *silesiacus*, known from the Germanic Basin, are proposed for the Tatra Mountains. The *Dadocrinus* Zone is distinguished in the Tatricum and Fatricum complexes; both the *acutangulus* and *dubius* Zones are distinguished in the Tatricum complex, and the *silesiacus* Zone is distinguished in the Fatricum complex. The crinoid remains determined previously as *Encrinus* and *Entrochus* were found to have no stratigraphic value in the present state of research. The crinoids suggest a late Olenekian age for the limestones from Giewont, a latest Bithynian–early Pelsonian age for the limestones from Krzesanica and a middle Pelsonian age for the limestones of Ciemniak. The dolomites from the Filipka Valley quarry are dated as late Pelsonian–early Illyrian.

Key words: Middle Triassic, Tatra Mountains, stratigraphy, taxonomy, crinoids.

Introduction

The Tatra Mountains, in which three tectonic units (Hronicum, Fatricum and Tatricum) are recognizable, are poor in Triassic fossils (except in the Rhaetian sediments). Ammonoids and conodonts only occur within relatively small-sized areas in a complex belonging to the Hronicum in the Wielkie Koryciska and Siwiańskie Turnie (Zawidzka 1972; Kotański 1973a; Gaździcki 1978). Therefore, other groups of fossils, like crinoids or calcareous algae (Dasycladaceae), are used in Triassic biozonation. Amongst the crinoids, the genus *Dadocrinus* Meyer is the most important stratigraphically, considered to be an indicator of the early Anisian (e.g. Kotański 1958, 1959b, 1973b; Piotrowski 1965; Zawidzka 1967), however, other taxa can also be used. Up to now, in the Tatras, only *D. grundeyi* Langenhan (Lefeld 1958) and *D. gracilis* (Buch) (Passendorfer 1951; Jaglarz 2004) have been found in the Tatricum complex, and *Pentacrinus bavaricus* (Goldfuss) (Goetel 1917) in the Fatricum complex. In both these units the following taxa occur: *Dadocrinus* sp. (e.g. Kotański 1958, 1959b, 1963a,b, 1973b; Grochocka-Rećko 1963; Szulczewski 1963; Iwanow 1965; Piotrowski 1965; Bełka & Gaździcki 1976), *Encrinus* sp. (e.g. Kotański 1958, 1963a,b; Guzik 1963; Sochaczewski 1997), *Encrinus liliiformis* Lamarck (Uhlig 1897; Rabowski 1959; Kotański 1963a, 1965; Passendorfer 1983), *Entrochus* sp. (Kotański 1963b; Piotrowski 1965; Bełka & Gaździcki 1976), *Pentacrinus* sp. (Radwański 1968; Gaździcki 1974). Although the Hronicum complex deposits (upper Anisian–Ladinian) yield numerous fossil crinoids, up to now the crinoids remain undescribed. Only one columnal of *Traumatocrinus* cf. *caudex* (Dittmar) has been described from Ladinian age sediments (Głuchowski 2002). Therefore, the assignment of crinoids from the Tatras is poorly known and in need of critical revision. In addition, preliminary data presented in this paper indicate the presence of stratigraphically important species.

Stratigraphic significance of Triassic crinoids

Papers concerning the application of Triassic crinoid stratigraphy, are usually related to investigations of epicontinental deposits of Germanic facies, because the majority of whole crinoid cups or calyces have been found in that area. Due to the completeness of fossil crinoids in the Germanic facies, taxonomic determination to the species level can be made. In addition, the conodont zonation of the Muschelkalk deposits is well established. The Upper Muschelkalk, within the ammonoid zonation, allows precise placement of crinoid stratigraphic ranges. On this basis, a crinoid zonation has been proposed (Hagdorn & Głuchowski 1993) for Upper Silesia (southern Poland), which is also useful in neighbouring areas: eastern Germany, Holy Cross Mountains and Sudetes Mountains (Hagdorn & Głuchowski 1993; Salamon 2003; Salamon et al. 2003; Głuchowski & Salamon 2005), as well as in the Mecsek Mountains in Hungary (Hagdorn et al. 1997). Except for the *Dadocrinus* and *liliiformis* Zones, crinoid biozones are not distinguished in the western part of the Germanic Basin, because there is a lack of important stratigraphic taxa (Hagdorn & Głuchowski 1993). However, the latest observations (Niedźwiedzki & Salamon 2002) indicate that the boundaries of at least some crinoid zones may be slightly diachronic, although they have strati-

graphic value, especially where ammonites and conodonts are absent. Previous investigations of Tethyan Middle Triassic crinoids are limited, because articulate specimens, or cups, are very rare. *Dadocrinus* is treated as the Tethyan index of the Lower Anisian and enables correlation with the Germanic Basin (e.g. Lefeld 1958; Kotański 1959b; Piotrowski 1965), *Encrinus liliiformis*, which marks the Illyrian–Ladinian interval (Kotański 1963b, 1965; Senkowiczowa & Kotański 1979; Kotański & Zawidzka 1979), and *Traumatocrinus* Wöhrmann, which characterizes the Ladinian (Głuchowski 2002). Until now, however, none of the crinoid zones have been distinguished in the Tatra Mountains, although nearly all species can be correlated with the crinoid zones in the Germanic Basin, which also occur in the eastern and southern Alps (Kristan-Tollmann & Tollmann 1967; Kristan-Tollmann & Spendlingwimmer 1975; Hagdorn et al. 1997). In the eastern part of the Tethys and elsewhere (Amur Basin, New Zealand), only three stratigraphically important taxa from the European Middle Triassic, namely *Dadocrinus gracilis*, *Holocrinus dubius* (Goldfuss) and *Eckicrinus radiatus* (Schauroth) are known. However, their determination and/or stratigraphic position have been questioned (Bather 1918; Kristan-Tollmann 1988; Hagdorn et al. 1997; Eagle 2003; Głuchowski & Salamon 2005).

Materials and methods

During investigations in 2003–2004 several dozen sites from all three tectonic-facies units of the Polish part of the Tatra Mountains were sampled. About 40 rock samples consisting of limestones and dolomites with macroscopic crinoid ossicles were taken from the Tatricum, Fatricum and Hronicum complexes. They were subjected to chemical maceration according to the methods described by Boczarowski (2001). The rocks were then etched in CH_3COOH and buffered by $(CH_3COO)_2Ca$. According to Boczarowski (2001) the best results were obtained using a mixture of ½ supersaturated $(CH_3COO)_2Ca$, ¼ 30 % CH_3COOH, and ¼ H_2O. Most crinoid ossicles were not well preserved enough for taxonomic determination. Therefore, only the samples from the following sites were chosen for investigation (see also Fig. 1):

- The southern wall of the Mt Giewont (Tatricum complex); at the descent by the tourist path toward the Wyżna Kondracka Pass, near the end of the securing chains. The crinoids occur within black micritic limestones, in the highest part of the Triassic complex, near the boundary with Jurassic limestones. Over 100 columnals and short (up to 6 columnals) stem fragments belonging exclusively to *Dadocrinus* were collected. Elements of *Holocrinus acutangulus* (Meyer) were not associated with *Dadocrinus*.
- The top of the Mt Krzesanica (the Czerwone Wierchy Mts group, Tatricum complex). The crinoids occur within intercalations of black, micritic limestones forming interbeddings within vermicular and breccia limestones. A few columnals of *Holocrinus acutangulus* as well as numerous columnals of the Encrinidae have been documented. *Dadocrinus* columnals were not found.
- Eastern part of the Mt Ciemniak top (the Czerwone Wierchy Mts group, Tatricum complex). Crinoids found within black-grey micritic limestones intercalations, forming interbeddings within dolomites. A few columnals belonging to *Holocrinus dubius* and more frequent columnals of Encrinidae have been documented.
- Small, abandoned quarry in the Filipka Valley (Fatricum complex) at the southern base of the Mt Filipczański Wierch. The organodetrical dolomite samples are from lithological A Unit (see Sochaczewski 1997 for detailed locality and lithological description). Mass occurrence of large (up to 9 mm), but poorly preserved, isolated columnals and stem fragments (up to 10 columnals) of crinoids have been found. The majority of columnals do not preserve their articular facets, however, in some cases they are poorly visible. Columnals characterized by a large

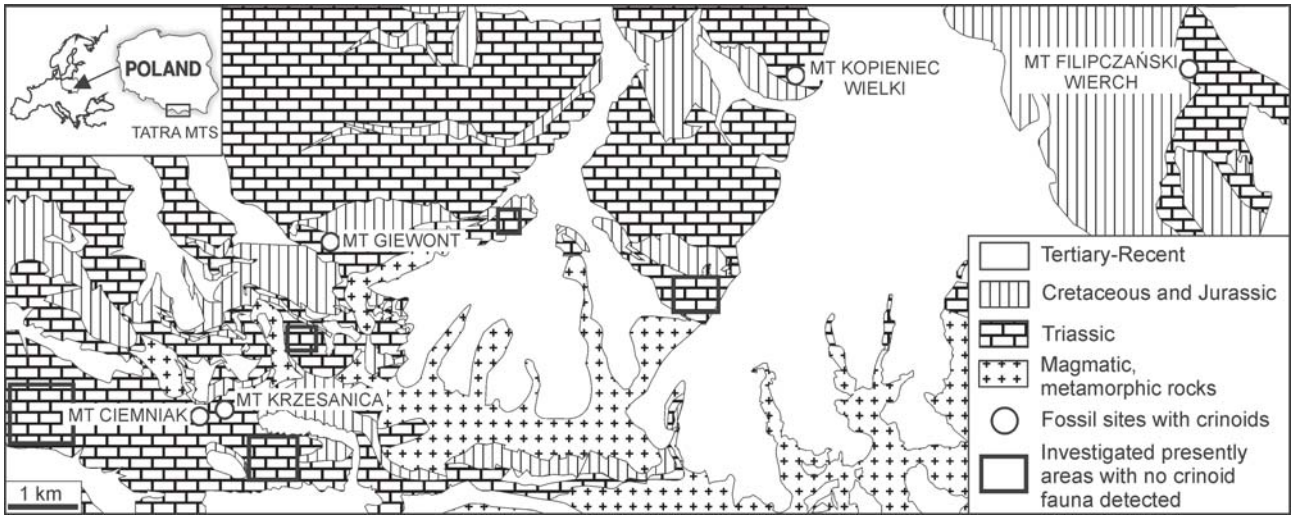

Fig. 1. Geological map of the Tatra Mountains (after Bac-Moszaszwili et al. 1979; modified).

lumen were assigned to *Silesiacrinus* cf. *silesiacus* (Beyrich), and columnals with considerably smaller lumen were assigned to the Encrinidae.

◆ The top of the Mt Kopieniec Wielki (Fatricum complex); from the intercalations of black micritic limestone, which form interbeds within dolomites. Isolated columnals belonging to Encrinidae, not associated with other crinoid remains, have been documented.

Taxonomic review

Depository referred to in this paper is: MGUWr — Museum of Geological Sciences of Wrocław University.

Class **Crinoidea** Miller, 1821
Subclass **Articulata** Zittel, 1879
Order **Millericrinida** Sieverts-Doreck, 1952
Suborder **Millericrinina** Sieverts-Doreck, 1952
Family **Dadocrinidae** Lowenstam, 1942
Dadocrinus Meyer, 1847
Type species *Encrinus gracilis* Buch, 1845, p. 27.

***Dadocrinus* sp.** Fig. 2A–E; Fig. 3B

Material: 58 free columnals; single holdfast; 4 strongly weathered rock surfaces with isolated columnals; 3 polished slabs; MGUWr-5353s.

Description: Columnals low and rounded; maximum diameter 3.0 mm. The distal columnals are higher. Crenulation pattern multiradiate; crenulae thick, very short in proxistele to long in dististele. Columnal latera flat or rarely convex. Lumen wide, circular or slightly pentagonal. Discoidal holdfast.

Family indet.
Silesiacrinus Hagdorn et Głuchowski, 1993
Type species *Entrochus silesiacus* Beyrich, 1857, p. 46.

***Silesiacrinus* cf. *silesiacus* (Beyrich, 1857)**
Fig. 2F; Fig. 3C

1993 *Silesiacrinus silesiacus* (Beyrich) — Hagdorn & Głuchowski, p. 171, 175, fig. 10/1
1996 *Silesiacrinus silesiacus* (Beyrich) — Hagdorn et al., p. 65–68, pl. 6

Material: 1 free columnal; 3 strongly weathered rock surfaces with numerous isolated columnals; 1 polished slab; MGUWr-5354s.

Description: Large columnals; maximum diameter 9 mm. Columnals low, circular and with straight latera. Articular facets with multiradiate crenulation and long culmina; distinct epifacet. Lumen very wide, circular or rarely pentalobate.

Remarks: This taxon only occurs in the samples from the Filipka Valley quarry. Large columnals with narrow and oval lumen, assigned here to encrinids (Filipka Valley quarry), are accompanied by columnals with wide lumen belonging in our opinion to *S.* cf. *silesiacus*. This occurrence is supported by H. Hagdorn (pers. comm. November 2004).

Order **Isocrinida** Sieverts-Doreck, 1952
Family **Holocrinidae** Jaekel, 1918
Holocrinus Wachsmuth et Springer, 1886
Type species *Encrinus beyrichi* Picard, 1883, p. 199

Holocrinus acutangulus (Meyer, 1847) Fig. 2G–I

1847 *Chelocrinus ?acutangulus* — Meyer, 1847, pl. 32, figs. 7, 18, 21–26
1849 *Chelocrinus ?acutangulus* — Meyer, p. 272–275, tab. XXXXII, figs. 17–18, 21–26
1883 *Encrinus beyrichi* — Picard, p. 199
1886 *?Holocrinus beyrichi* Wagner — Wachsmuth & Springer, p. 139
1893 *Holocrinus wagneri* Benecke, 1887 — Jaekel, p. 203–204
1993 *Holocrinus acutangulus* (Meyer, 1847) — Hagdorn & Głuchowski, p. fig. 6

Material: 9 free columnals; 3 strongly weathered rock surfaces with columnals; MGUWr-5355 s.

Description: Columnals stellate to pentagonal or subpentagonal, fairly small; maximum diameter 3.1 mm. Small and circular lumen. The crenulation pattern multiradiate with relatively long culmina. The adradial crenulae weakly developed in form of nodules. Petal floors narrow and lanceolate. Nodals slightly higher than internodals, with five relatively large and deeply impressed elliptical cirrus scars.

Holocrinus dubius (Goldfuss, 1831) Fig. 2J–K

1831 *Pentacrinites dubius* — Goldfuss, 176, pl. 53, fig. 6
1835 *Encrinites dubius* (Goldfuss, 1831) — Quenstedt, p. 225–228, pl. 4, fig. 2
1857 *Entrochus dubius* (Goldfuss, 1831) — Beyrich, p. 37, 46
1918 *Isocrinus dubius* (Goldfuss, 1831) — Bather, p. 253
1926 *Entrochus dubius* (Goldfuss, 1831) — Assmann, p. 515
1928 *Entrochus dubius* (Goldfuss, 1831) — Schmidt, p. 127, fig. 245
1982 *Tyrolecrinus dubius* (Goldfuss, 1831) — Klikushin, p. 307
1993 *Holocrinus dubius* (Goldfuss, 1831) — Hagdorn, p. 213, figs. 1-2

Material: 13 free columnals; 4 strongly weathered rock surfaces with isolated columnals; MGUWr-5356s.

Description: Columnals pentagonal or subpentagonal to substellate; maximum diameter 4.6 mm. Small and circular lumen. Articular facets covered by thick marginal and denticulate adradial crenulae. Smallest columnals with multiradiate crenulation pattern and long culmina. Petal floors well developed and wide, lanceolate or pyriform. Nodals with 5 deeply impressed, relatively small and elliptical cirrus scars; cirrus scars with a distinct transverse ridge.

Order **Encrinida** Matsumoto, 1929
[nom. transl. Hagdorn, 1987]
Family **Encrinidae** Dujardin et Hupé, 1862
Encrinidae gen. et sp. indet. Fig. 2L; Fig. 3A

Material: 38 free columnals; 2 strongly weathered rock surfaces with isolated columnals; MGUWr-5357s.

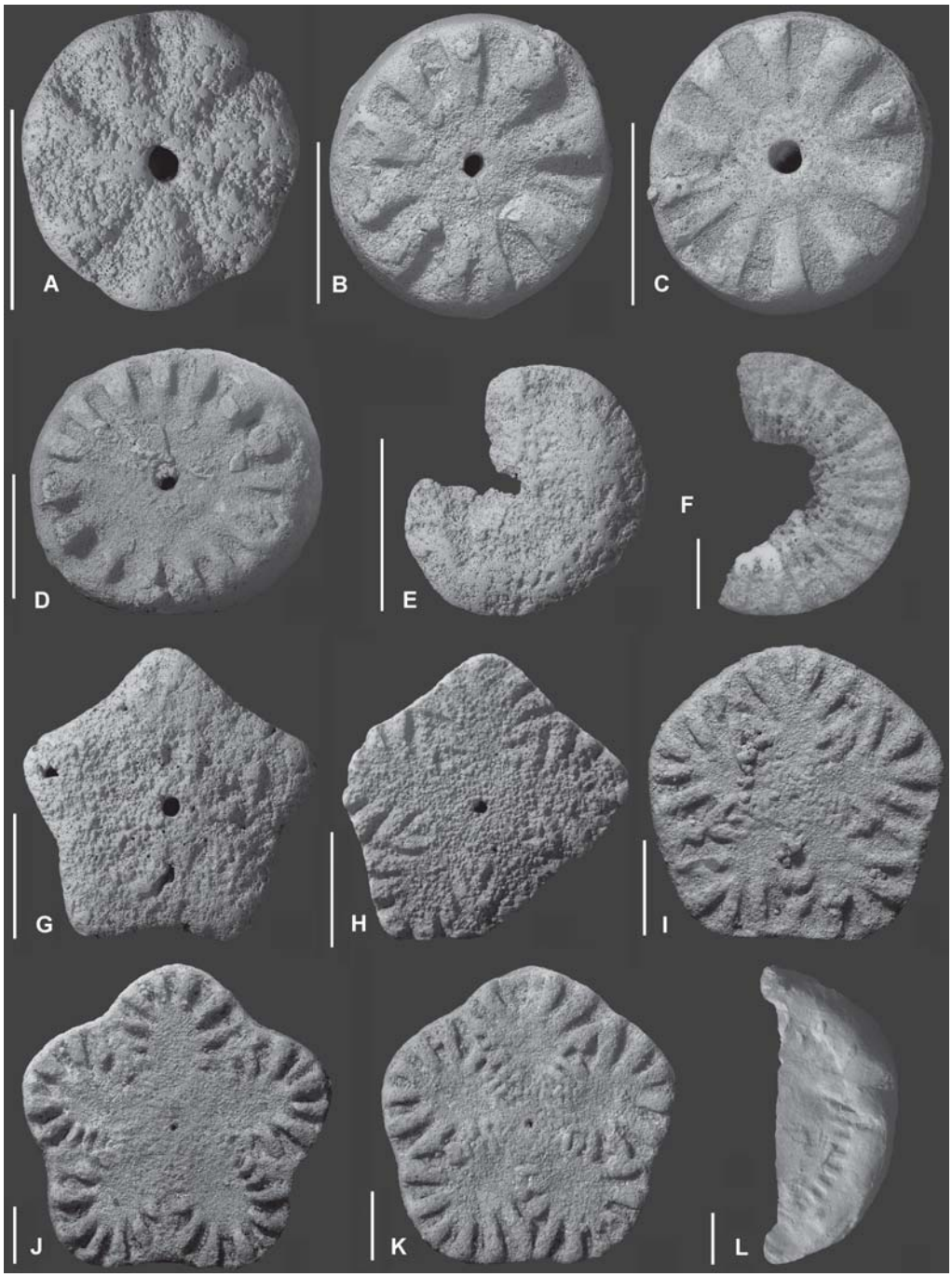

Fig. 2. Columnals from the Tatra Mountains; scale bars 1 mm. **A–E** — *Dadocrinus* sp. (Mt Giewont). A — juvenile?; MGUWr-5353s/D1. B–D — distal/median columnals; MGUWr-5353s/D2-4. E — part of holdfast; MGUWr-5353s/D5. **F** — *Silesiacrinus* cf. *silesiacus* (Beyrich) (Filipka Valley); MGUWr-5354s/S1. **G–I** — *Holocrinus acutangulus* (Meyer) (Mt Krzesanica). G–H — medial/proximal columnals; MGUWr-5355s/B1-2. I — distal columnal; MGUWr-5340/B3. **J–K** — *Holocrinus dubius* (Goldfuss) (Mt Ciemniak); MGUWr-5356s/H4–5. J — proximal columnal; MGUWr-5356s/H6. K — median/distal columnal; MGUWr-5356s/H7. **L** — columnal of Encrinidae sp. et gen. indet. (Mt Kopieniec Wielki); MGUWr-5357s/E1.

Description: Proximal columnals pentagonal, distal columnals rounded and very low. Maximum diameter 8.5 mm. Latera smooth or convex. Multiradiate crenulation with well-developed granulated perilumen. Some columnals with petaloid crenulation, others distinctly pentalobate and bordered by thick and short crenulae occur. Distal columnals higher than median or proximal, with convex latera. Lumen relatively wide and round, in some cases surrounded by more or less developed pentalobate to pentagonal and ornamented perilumen.

Remarks: Due to the smaller number of isolated columnals we are not able to distinguish distinct morpho-

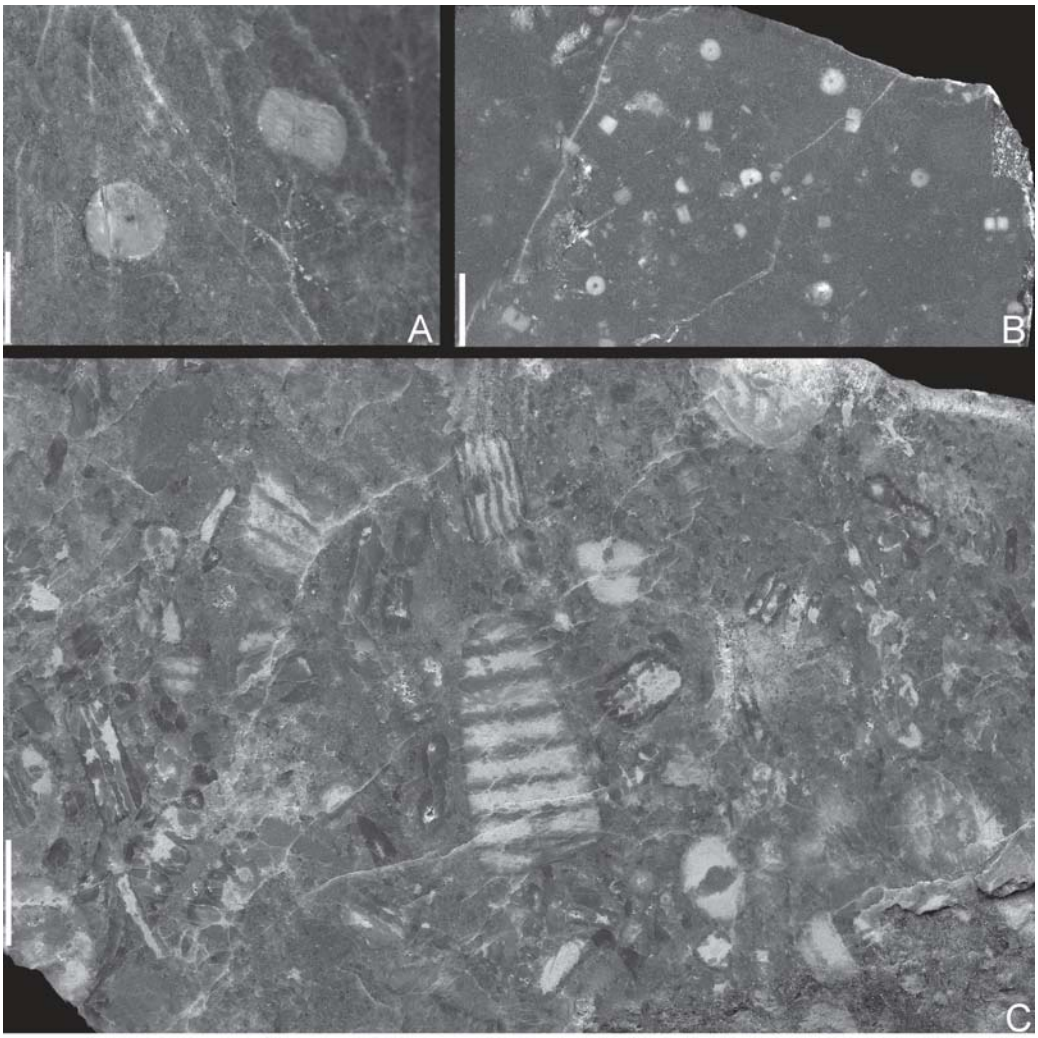

Fig. 3. Crinoids on the surface of polished slabs. Tatra Mountains; scale bars 10 mm. **A** — Encrinidae sp. et gen. indet. (Mt Kopieniec Wielki); MGUWr-5357s/E2. **B** — *Dadocrinus* sp. (Giewont); MGUWr-5353s/D9. **C** — *Silesiacrinus* cf. *silesiacus* (Filipka Valley); MGUWr-5354s/S8.

types. Hagdorn et al. (1996) distinguished five morphotypes among their investigated material. Salamon (2003), on the other hand, has distinguished six morphotypes.

Previous data on crinoids from the Tatra Mountains

Up to now only one locality with crinoid calyces has been found in the Tatra Mountains. Within the 3 cm thick 3 m lateral bed, occurring in the upper part of the Triassic outcrops at Zawrat Kasprowy (Tatricum), Lefeld (1958) found ca. 120 calyces and crowns of *Dadocrinus grundeyi*. The remaining reports of Tatras crinoids (e.g. Kotański 1959a,b; Piotrowski 1965; Sochaczewski 1997) are based on single elements, especially columnals; their verification is not possible because there is not photographic or descriptive documentation. *Dadocrinus* and *Encrinus* are the most commonly described Triassic taxa from the Tatra Mountains. Most authors did not explain their taxonomical assignment (e.g. Kotański 1959a; Zawidzka 1967; Kulikowski 1967). They treated "small" columnals as *Dadocrinus* (e.g. Kotański 1959b, 1973b; Szulczewski 1963; Piotrowski 1965), and "large" columnals as *Encrinus* (Guzik 1963; Kotański 1958, 1963a; Sochaczewski 1997). However, size alone cannot be the discriminative taxonomical feature, because of ontogenetic development. Moreover, when analysing the well-recognized crinoids from the Germanic Basin, it is possible to indicate different genera within each of these two size classes. Features like the external shape of columnaria and characters of the facet are crucial for their taxonomical determination. Morphology of calyx plates or brachials is also important. Therefore, the determinations of the specimens of *Encrinus* and most of the specimens of *Dadocrinus* are not reliable, and cannot be used as the basis for stratigraphic correlation. Also the assignment of isolated columnals from the uppermost Triassic beds of the Giewont to *D. gracilis* by Passendorfer (1951) was not correct, because species identification on

the basis of isolated ossicles of *Dadocrinus* is not reliable (e.g. Hagdorn & Głuchowski 1993). Similar species identification of crinoid elements from the Tatricum and/or Hronicum complexes, assigned to *D. gracilis* by Kotański & Zawidzka (1979), Senkowiczowa & Kotański (1979) and Jaglarz (2004) is also not reliable because the identification was based upon isolated ossicles. The lower boundary of the *Dadocrinus* stratigraphic range is another crucial problem. As mentioned above, in the Tatra Mountains, *Dadocrinus* is treated as the lower Anisian index, on the basis of analogous occurrence of this crinoid in Upper Silesia. *Dadocrinus* appears firstly at the base of the Lower Muschelkalk in Upper Silesia and the upper part of the Roetian in the Holy Cross Mountains (e.g. Hagdorn & Głuchowski 1993; Salamon 2003). Both deposits are traditionally dated as early Anisian, however, they do not contain any stratigraphically significant conodonts and ammonoids (Trammer 1975; Zawidzka 1975). Magnetostratigraphic investigations provide late Olenekian age to the lowermost part of the Lower Muschelkalk (lower part of *Dadocrinus* Zone) in Poland (Nawrocki & Szulc 2000). In addition, *Entrochus* is not stratigraphically significant because: 1 — lack of documentation and descriptions of diagnostic features of columnals found in the Tatra Mountains (e.g. Kotański 1963b; Piotrowski 1965) and assigned to *Entrochus*, excludes their verification and species determination; and 2 — *Entrochus* is a parataxonomic genus not related to a biological species (Hagdorn 1995). Many species earlier assigned to the *Entrochus* are currently assigned to different genera such as *Holocrinus dubius* and *Eckicrinus radiatus*. *Encrinus liliiformis* has been mentioned many times from Tatras (Uhlig 1897; Rabowski 1959; Kotański 1963a, 1965; Kotański & Zawidzka 1979; Senkowiczowa & Kotański 1979; Passendorfer 1983), but its presence cannot be considered valid because these papers do not include descriptions or illustrations of *E. liliiformis*. For example, Kotański (1963a, p. 351) only wrote, that "crinoids in the Strążyńska Valley … were … usually … determined as *E. liliiformis*"; and Passendorfer (1983) mentioned numerous columnals of this species from the Strążyńska Valley, but in his description he paid attention only to the large sizes of the columnals, not a diagnostic feature of *E. liliiformis*. According to Rabowski (1959) *E.* cf. *liliiformis* occurs in the uppermost Triassic beds in Giewont. However, our investigations and those of other authors (i.e. Passendorfer 1951; Kotański 1959b), does not prove the occurrence of crinoids other than *Dadocrinus*. Additionally, the limestones are latest Olenekian or earliest Anisian in age, so they were deposited before the appearance of the species mentioned (Illyrian). Therefore, the determination of Rabowski (1959) is incorrect. It is not clear what is the age of the sediments with the columnals treated as *E. liliiformis*. According to Kotański & Zawidzka (1979), it occurs only in the Illyrian, however, Kotański (1963b, 1965), Senkowiczowa & Kotański (1979) and Passendorfer (1983) found *E. liliiformis* in the Ladinian strata as well. *Silesiacrinus silesiacus* was mentioned from the Tatra Mountains only by Hagdorn & Głuchowski (1993), but they did not mention any locality and provided no documentation on this finding. It is also not known whether this crinoid comes from the Fatricum or Hronicum complexes.

The stratigraphic significance of Tatras crinoids

The data presented in the paper allow the presence of four crinoid biozones in the Tatra Mountains already known from the eastern part of the Germanic Basin and Mecsek Mts Muschelkalk: *Dadocrinus* Zone, *acutangulus* Zone, *dubius* Zone and *silesiacus* Zone (Fig. 4). The oldest, *Dadocrinus* Zone, covers both the Tatricum (Giewont — see data in this paper; Zawrat Kasprowy — see data in Lefeld 1958) and Fatricum complexes (*Dadocrinus* crinoids described and illustrated by Kotański 1963a). The *acutangulus* and *dubius* Zones were distinguished in a complex belonging to the Tatricum (Czerwone Wierchy Massif), and the *silesiacus* Zone in the Fatricum complex (the Filipka Valley). The problem of the existence of the *liliiformis* Zone in the Tatra Mountains has not been resolved yet and needs further investigation. The small size of specimens limited to a few sites, poorly preserved crinoid elements in most localities and very poor crinoid data in older publications multiply all the problems when dealing with the precise geographical and stratigraphical ranges of particular zones. Therefore, the absence of particular zones in the Fatricum or Tatricum complexes is certainly caused by insufficient data on crinoid fauna from the Tatra Mts. The stratigraphic ranges of particular zones distinguished in the Tatras are based on the correlation with the well-documented crinoid zonation of the Germanic Basin. In addition, the Tatras crinoids allow age verification of investigated exposures. The limestones from the Ciemniak and Krzesanica peaks, have been dated as Middle Triassic (Bac-Moszaszwili et al. 1979) or Anisian (Kostiukow 1963). The holocrinids suggest a latest Bithynian–early Pelsonian age for the limestones from Krzesanica and a middle Pelsonian age for the limestones Ciemniak. The dolomites from the Filipka Valley quarry were dated as Anisian–Ladinian (Bac-Moszaszwili et al. 1979). Sochaczewski (1997) determined the crinoid fragments from the quarry as 'probably *Encrinus*' and he assigned the investigated dolomites to the Ladinian age. However, *Silesiacrinus* cf. *silesiacus* collected by the authors indicates an earlier, Anisian age, because this species and genus occurs in the late Pelsonian–early Illyrian interval (Hagdorn & Głuchowski 1993) in the Germanic Basin as well as in the Tethys; it is also possible that it occurs in the late Illyrian (Kristan-Tollmann & Tollmann 1967; Hagdorn et al. 1997). The limestone intercalations within dolomites in the Wielki Kopieniec and Mały Kopieniec area have been described as limestones containing *Dadocrinus* sp. of Anisian age (Bac-Moszaszwili et al. 1979). The limestones on the top of the Wielki Kopieniec contain only numerous Encrinidae and no *Dadocrinus* representatives. Thus, part of the crinoidal limestones from the Kopieniec

area is not related to dadocrinid accumulations. Encrinidae occurred in the western Tethys from the Pelsonian to the Carnian (Hagdorn et al. 1997); so an early Anisian age of the limestones from the Wielki Kopienic is improbable. According to Kotański (1959b), the mass occurrence of *Dadocrinus* on the Giewont indicates early Anisian age. However, according to both, Kotański (1959b) and the author's observations, the limestones from the Giewont as well as the bed with mass occurrences of calyces from the Zawrat Kasprowy (Lefeld 1958), are not associated with any other crinoid genera. According to data obtained from Upper Silesia, Holy Cross Mountains and Sudetes (Hagdorn & Głuchowski 1993; Salamon 2003; Głuchowski & Salamon 2005) such monospecific dadocrinid accumulations define the lower part of the *Dadocrinus* Zone. Magnetostratigraphic data (Nawrocki & Szulc 2000) suggest the late Olenekian age.

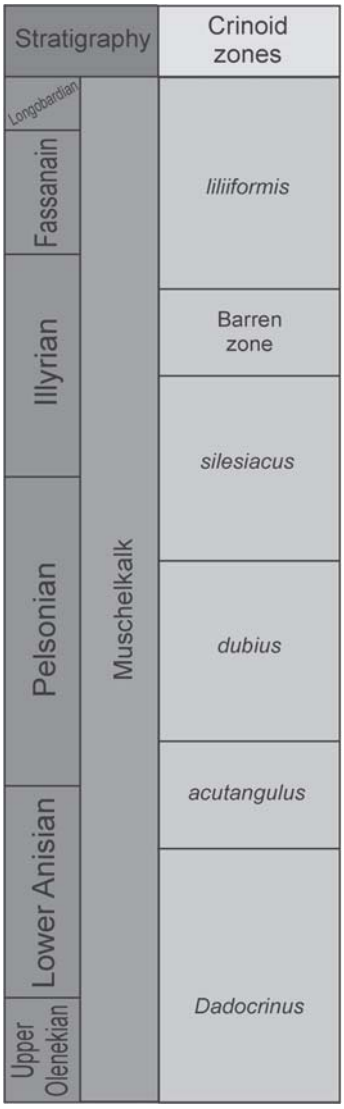

Fig. 4. Crinoid Zones distiguished by Hagdorn & Głuchowski (1993); after Hagdorn & Głuchowski (1993, Fig. 1), slightly modified.

Conclusions

- All stratigraphically important Anisian crinoids known from the eastern part of the Germanic Basin: *Dadocrinus* species, *Holocrinus acutangulus*, *Holocrinus dubius*, *Silesiacrinus silesiacus*, occur in the Triassic strata of the Polish part of the Tatra Mountains. Therefore, it is possible to confirm the Triassic crinoidal zonation for the Tatra Mountains based on the biostratigraphic scheme from the Germanic Basin and Mecsek Muschelkalk. Such a zonation has fundamental significance for the Tatras by allowing more precise dating of the Anisian deposits.
- The *Dadocrinus* Zone is distinguished in the Tatricum and Fatricum complexes; both the *acutangulus* and *dubius* Zones are distinguished in the Tatricum complex, and the *silesiacus* Zone is distinguished in the Fatricum complex. The presence of the *liliiformis* Zone in the Triassic sequence of the Tatra Mountains is still unresolved and needs further investigations.
- Previously described taxa from the Triassic strata of the Polish part of the Tatra Mountains cannot be used for stratigraphic investigations because of a lack of any documentation on these findings. Additionally, the majority of them were determined to the genus level only, and genera such as *Encrinus* or *Pentacrinus* have very wide stratigraphic ranges. *Entrochus*, on the other hand, is a parataxonomic genus, and thus it is stratigraphically unimportant.

Acknowledgments: We would like to express our warm thanks to the authorities and workers of the National Park of the Tatra Mountains, for permission and help during investigations. We thank Dr. Hans Hagdorn (Muschelkalkmuseum Ingelfingen, Germany) for help in determination of the crinoids, and Prof. Dr. Hab. Alfred Uchman (Jagiellonian University, Cracow, Poland) for access to valuable bibliographic data. We appreciate the Teisseyre family library, donated to the library of the Institute of Geological Sciences of University of Wrocław. Special thanks are also due to Dr. Torrey Nyborg (Loma Linda University, California, United States) for improving the English of the paper. Authors express also thanks to Drs. Hans Hess (Binningen, Switzerland), Riccardo Manni ("La Sapienza" University, Roma, Italy) and Jozef Michalík (Slovak Academy of Sciences, Bratislava, Slovak Republic) for reviews that improved our paper. The investigations were benefited from the financial support of the Institute of Geological Sciences, University of Wrocław (Grant 2022/W/ING/04-28; Robert Niedźwiedzki); the Paleontological Society, PalSIRP — *Sepkoski Grants* 2005 and the Foundation for Polish Science (FNP) — *Domestic Grants for Young Scientists* 2005 (Mariusz A. Salamon).

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