

# **ASZULCICRINUS, A NEW GENUS OF THE TRIASSIC CRINOID FAMILY DADOCRINIDAE (ARTICULATA; ENCRINIDA) FROM POLAND**

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**Abstract:** The new genus and species *Aszulcicrinus pentebrachiatus* of the family Dadocrinidae from the early Middle Triassic Lower Gogolin Formation of Upper Silesia Upland is described. In contrast to *Dadocrinus*, the second primibrachial of *Aszulcicrinus* is not axillary for articulation with two arms but articulates with a third primibrachial and the first pinnule. This character results in five unbranched arms, which is unique in the order Encrinida. The significance of this character is discussed and pedomorphic or ecophenotypic explanations are excluded. The presence of only five unbranched arms predominates through the ontogeny of *Aszulcicrinus* from early postlarval to adult stage. Within the family Dadocrinidae (*Aszulcicrinus* - *Dadocrinus* - *Carnallicrinus*), a phylogenetic trend towards size increase coincident with increasing arm number and denser pinnulation is interpreted as an improvement in filter-feeding efficiency. The sedimentological and taphonomic setting of the obituational conservation lagerstätte of the type locality is described.

**Key words:** Crinoidea, Middle Triassic, early Anisian, Upper Silesia, functional morphology, taphonomy.

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## **INTRODUCTION**

The Triassic crinoid family Dadocrinidae was established by Lowenstam (1942) to include the early Middle Triassic genus *Dadocrinus* von Meyer, 1847 and its younger synonyms *Calathocrinus* v. Meyer, 1847, *Cremacrinus* Jaekel, 1918, and *Recoarocrinus* Gislén, 1924. Because of its uniserial arms, he assigned Dadocrinidae to Order Millericrinida (see also Lowenstam, 1978). Emphasizing the synostiosial articulations of basals and radials that are unlike millericrinids, the similarity with juvenile Encrinidae that have also uniserial arms and discoid or incrusting holdfasts of encrinid type, Hagdorn (1996) assigned Dadocrinidae to order Encrinida and later on transferred the 20-armed *Carnallicrinus* from Encrinidae to Dadocrinidae (Hagdorn, 2011). In the Revised Crinoid Treatise, Hess (2011) followed these assignments and revised the diagnosis of Family Dadocrinidae to include *Dadocrinus* and *Carnallicrinus*.

The type species of *Dadocrinus* is *Encrinus gracilis* von Buch, 1845 from the “Formazione à gracilis of the Vicentinian Prealps” in the vicinity of Recoaro (Italy). Buch (1845) compared this crinoid to similar Upper Silesian columns from Krappitz (Krapkowice), Petersdorf (Szobiszowice in Gliwice), and Lagiewnik (Łagiewniki) near Königshütte (Chorzów) to confirm his correlation of

the South Alpine and Upper Silesian Muschelkalk that he had based on the occurrence of the brachiopod *Tetractinella trigonella* in both regions. In a preliminary note, Meyer (1847) separated Buch’s species from *Encrinus*, introduced instead the genus *Dadocrinus*. The new genus was strictly rejected by Buch (1848a, b), who harshly criticized Meyer for making unnecessary genera. In his reply, Meyer (1848) added an initial sketch of a *Dadocrinus* crown, because the final figures of the specimens under description were not yet finished. A detailed description with figures of crowns, columns and holdfasts of Upper Silesian specimens from Chorzów and Łagiewniki, which he received from Hütteninspektor Mentzel, appeared in the 6<sup>th</sup> delivery of the first volume of Meyer’s “Palaeontographica” that was issued in July 1851 (Meyer, 1851). Subsequently, *Dadocrinus* was the subject of many palaeontological and stratigraphical research papers, mostly based on abundant and well preserved material, collected in quarries in Upper Silesia exposing the Gogolin Formation (e.g., Beyrich, 1857, 1858; Kunisch, 1883; Gürich, 1887). However, Meyer’s genus *Dadocrinus* was not accepted by the leading authorities, prior to Wachsmuth and Springer (1887) and Koenen (1887, 1895). Moreover, Wachsmuth and Springer (1887) separated the

large specimen from Gogolin that Kunisch (1883) regarded an adult individual of *Encrinurus gracilis* from this species and established the new species *D. kunischi*. A third species, *D. grundeyi*, characterized by exposed and externally visible infrabasals, was added by Langenhan (1903, 1911). This species concept, however, was much discussed. Jaekel (1918, figs 57–59) explained these nominal species as different growth stages of *D. kunischi*, and discerned a juvenile “Cyathocrinus stage”, the semiadult “Dictenocrinus stage” (*Dadocrinus gracilis*), and the adult “Hypalocrinus stage” (*D. kunischi*). Gasche (1939) and Lefeld (1958) described new specimens from the Austrian Alps and the Tatra Mountains respectively and treated these taxa as subspecies or developmental stages, Głuchowski (1986) regarded them ontogenetic stages or ecological varieties of one single species.

Basically, the diagnostic characters of the three nominal *Dadocrinus* species are the position and visibility of the infrabasal plates in the cup and the morphology of the proximal column. Indeed, these characters are not consistent, even within a single fossil association, as observed in large slabs with many individuals from Upper Silesian localities. In this context, Simms (1988) emphasized similarities of *Dadocrinus* and *Holocrinus* in cup, tegmen, and uniserial arms and concluded their close relationship. In *D. gracilis* he saw the earliest representative of Order Millericrinida and suggested the assignment of specimens with a dicyclic cup to a different family, leaving the established species in the family Dadocrinidae *sensu lato*. Different from the thinly plated cup of *Dadocrinus*, the barrel-shaped holocrinid cup has extremely thick basals and radials with zygosynostial articulations and extremely thin lumen.

Only recently, isolated columnals extracted from an exotic boulder of earliest Triassic (Induan, Griesbachian) age of

Oman (Wadi Wassit block) were described as *Baudicrinus krystyni* by Oji and Twitchett (2015). These authors assigned their new genus to Dadocrinidae and discussed possible scenarios of crinoid phylogeny along the P-T boundary. A second block of Griesbachian age from eastern Oman (“Assellah boulder”) contained more columnal and also cirral material of *Baudicrinus* that induced Brosse *et al.* (2018) to consider *Baudicrinus* to be an early representative of Holocrinidae. Hence, according to the presently known fossil record, Holocrinidae remain the oldest post-Palaeozoic crinoid lineage.

Diagnoses of Dadocrinidae and of the three nominal species plus a *Dadocrinus* sp. with five unbranched arms were provided by Hagdorn (1996), but he left a decision on their validity open. In the nominal *Dadocrinus* species, arms are branching at the axillary second primibrachials, in *Carnallicrinus* additionally at the axillary second secundibrachials. Hence, *Dadocrinus* regularly has ten arms, *Carnallicrinus* has twenty arms and the unnamed species has only five arms that remain unbranched. Viewing evolutionary trends in cup morphology and arm branching, Hagdorn (2011) indicated identical lineages among the Dadocrinidae and Encrinidae towards increasing arm numbers by repeated branching for improvement of the filtration fan efficiency. However, he did not formally establish a new species and genus for the five-armed dadocrinid. This is done in the present account.

It is the deeply felt duty and pleasure of the present author to contribute to the legacy of Achim Szulc, his friend and colleague in Triassic research, by dedicating to him a new genus of Triassic crinoids from Poland and herewith to honour his geological and stratigraphical work. The author will never forget the joint fieldwork on the Triassic in Poland and Germany, in Italy and France, in Israel and Jordan.

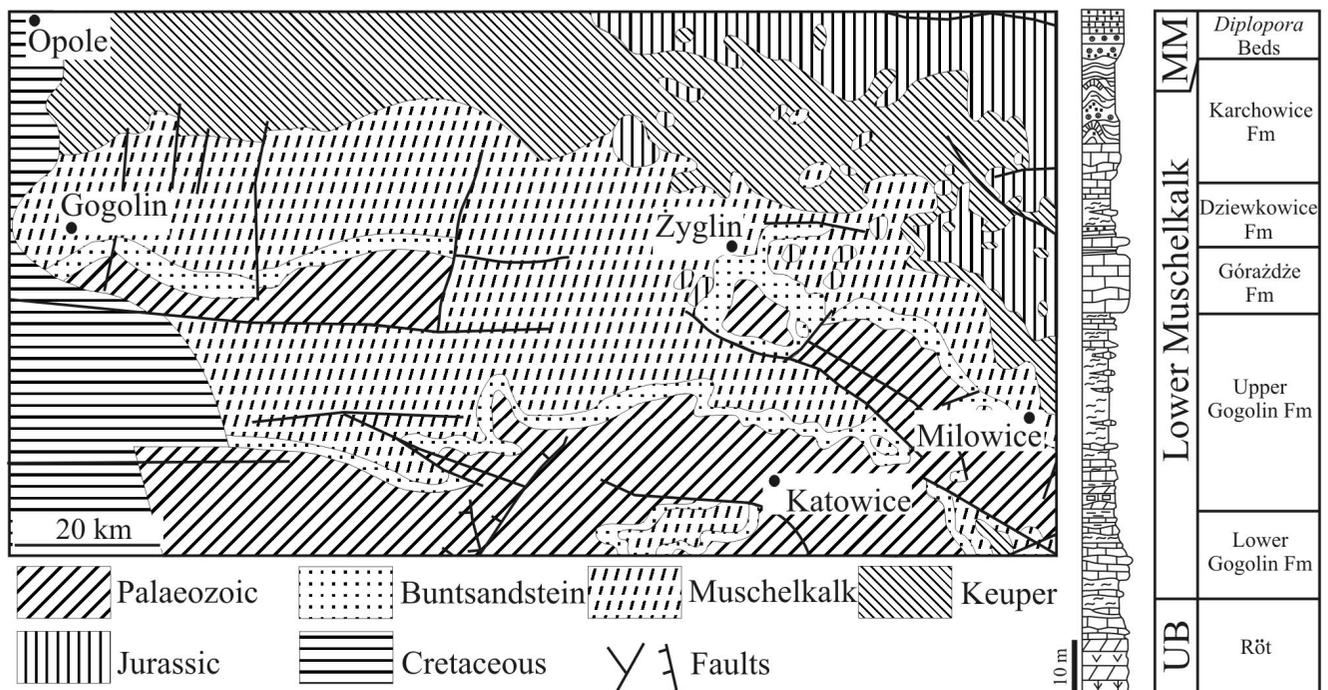


Fig. 1. Muschelkalk outcrop and generalized stratigraphic column of the Lower Muschelkalk in Upper Silesia. Modified from Szulc *et al.* (2009).

## GEOLOGICAL SETTING

The crinoids described here were collected in the 1980s in abandoned quarries in South Poland that exposed the Lower Gogolin Formation of the Lower Muschelkalk. The entire Muschelkalk succession with the Gogolin Formation at the base is cropping out from West to East in an up to 40-km-wide area, covered by a thin sheet of Pleistocene sediments, extending from Krapkowice, south of River Odra, and Gogolin to the Upper Silesia Upland (Fig. 1). There, the Muschelkalk outcrop surrounds the eastern margin of the Silesian Coal Basin. From its southeastern margin the Muschelkalk outcrop stretches farther to the East to the Małopolska Upland. However, this region yielded only indeterminable disarticulated dadocrinid material. The Gogolin limestones were historically quarried at an industrial scale next to Gogolin in extensive surface mines that yielded countless specimens, which were professionally collected and sold to museums. The quarries in eastern Upper Silesia Upland, the historical Zagłębie, were rather small pits for lime production, where fossil collecting was less common. Most of these quarries were filled up or recultivated during recent years.

In late Early and early Middle Triassic times, southern Poland was situated close to the northwestern opening of the Silesian Moravian Gate that connected the Central European Basin to the northern shelf of the Palaeo-Tethys (Szulc, 1999, 2000). However, Dadocrinidae occurred even earlier in the Subcarpathian Triassic (Wilczkowiec Beds of upper Röt, Senkowiczowa, 1976, p. 53) and in the uppermost Röt of the Holy Cross Mountains (Trammer, 1975), areas situated closer to the East Carpathian Gate, the pathway of the earliest immigration of Tethyan faunas into the Muschelkalk sea (Kozur, 1974; Hagdorn, 2020). From there *Dadocrinus* was likely to spread westwards. Because of increasing salinity towards the basin centre, the western boundary of Dadocrinidae is in the *Myophoria* Beds (Dornburg Member of uppermost Röt Formation) of Brandenburg (Germany), which, however, correlate with the Lower Gogolin Formation (Hagdorn and Simon, 2020). In the basal Muschelkalk of the North Sudetic Basin, *Dadocrinus* is still common (Głuchowski and Salamon, 2005).

*Dadocrinus* is a widespread genus of late Early and early Middle Triassic crinoids, which has been reported from extensive areas of the western Palaeo-Tethys, but the new five-armed genus has only been found in a small area of the Upper Silesia Upland (Region Silesia, województwo śląskie). Czeladź, the locality of the five-armed dadocrinid figured by Głuchowski (1986, pl. 1, figs 5–7), is also within this area. Articulated, ten-armed specimens of *Dadocrinus* in considerable numbers originate from the “Formazione à gracilis” of the Recoaro area and the Gogolin Formation of Gogolin and Łagiewniki, near Chorzów (Assmann, 1913, 1925, 1944). Among hundreds of complete *Dadocrinus* from the classic localities in Italy and historical Upper Silesia in collections, no five-armed individuals have been observed. However, a wider distribution of the new genus *Aszulcicrinus* cannot be excluded because isolated ossicles cannot be clearly distinguished from *Dadocrinus*.

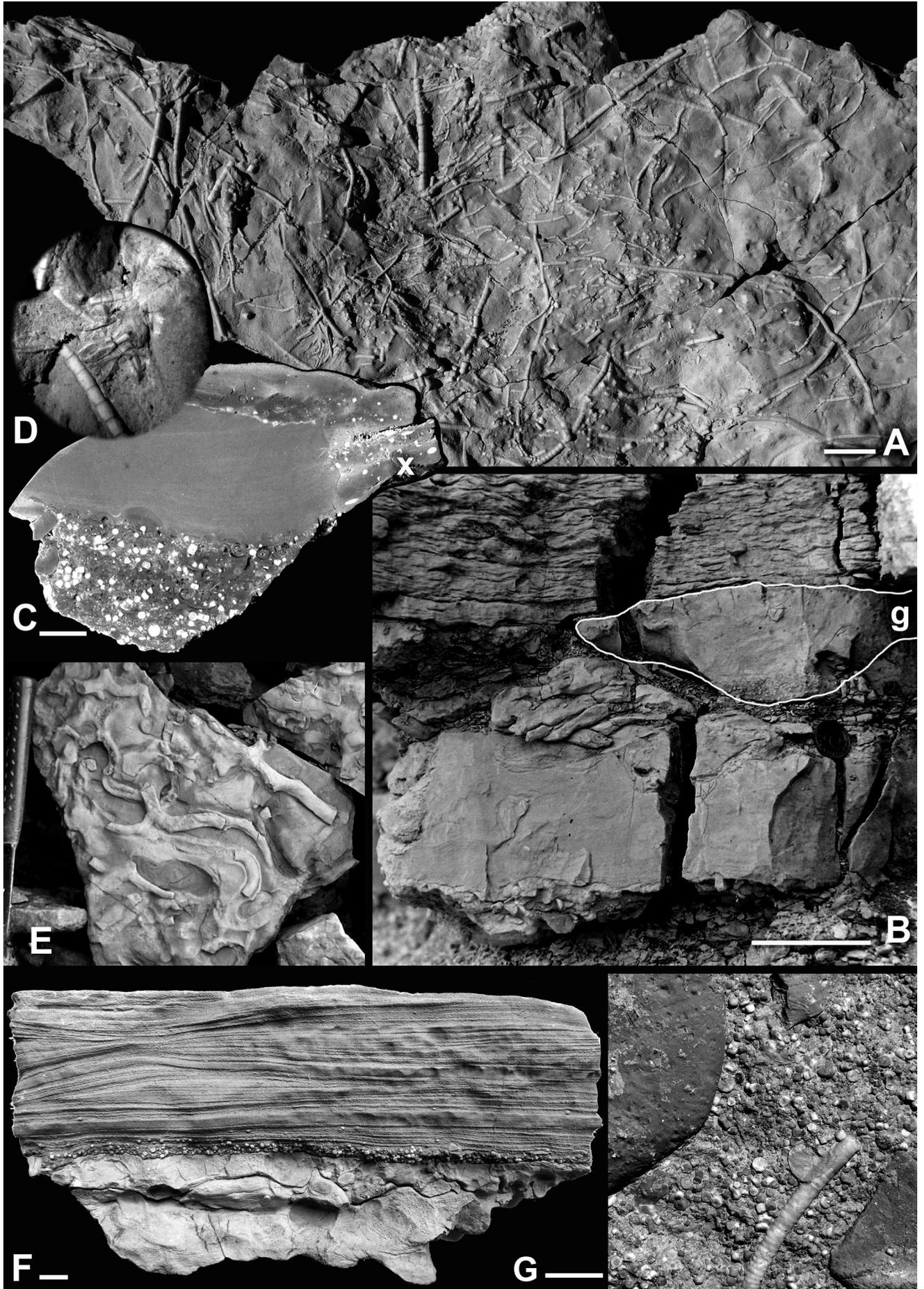
Because of its restricted stratigraphical distribution to the basal Muschelkalk, *Dadocrinus* was established as an index

fossil of the lower part of the early Anisian “assemblage zone with *Myophoria vulgaris*, *Beneckeia buchi* and *Dadocrinus*” by Kozur (1974), and of the *Dadocrinus* Zone (local range biozone) by Hagdorn and Głuchowski (1993). The latter corresponds to the Lower Gogolin Formation in Silesia and the Dornburg Member of the Röt Formation in Germany. The biostratigraphic scheme of early Middle Triassic crinoid zones developed by Hagdorn and Głuchowski (1993) was constrained by Głuchowski and Salamon (2005) for the North-Sudetic Basin and by Niedźwiedzki and Salamon (2006) for the Triassic in the Tatra Mountains. Following Nawrocki and Szulc (2000) they dated the lower part of the *Dadocrinus* zone to late Olenekian.

All specimens of the new dadocrinid come from the Lower Gogolin Formation. The term “Gogoliner Schichten” with lower and upper parts was formally introduced by Assmann (1944) to replace “Unterer Wellenkalk” (Assmann, 1913), because it could not be equated with the “Wellenkalk” (Jena Formation) in Germany. The Lower Gogolin Formation of the type area in Opole Silesia was subdivided into several formal members by Kowal-Linka (2009). However at the eastern margin of the Upper Silesian Coal Basin, changes in the facies hamper the identification of some of these members (Assmann, 1913, 1944). Sections of the neighbouring area in the Małopolska Upland were described by Chudzikiewicz (1983). However, no five-armed dadocrinid was observed in this area.

The new dadocrinid specimens under description were collected in 1987 at two localities, an abandoned quarry at Milowice, a district of Sosnowiec, and small active quarries at Żyglin, located north of Tarnowskie Góry (Fig. 1). In the Milowice quarry, approx. 10 m of the Lower Gogolin Formation were exposed. A continuous detailed section was not measured at this time. According to field notes, the section comprised from base to top thickly bedded crinoidal limestones, some of them with flat micritic intraclasts (Fig. 2G), representing the *Pecten* and *Dadocrinus* Limestone (Assmann, 1913, 1944), formally the Zakrzów Crinoidal Limestone Member (Kowal-Linka, 2009). In the upsection Wellenkalk Horizon (Assmann, 1913, 1944), thinly bedded wavy limestones (Wellenkalk facies) are followed by a yellowish, dedolomitic cellular limestone up to 30 cm thick, then intensively bioturbated, flaser-bedded wavy limestones with intercalated conglomeratic firmground beds, with dadocrinid ossicles at their erosional surfaces and topped by laminated or hummocky cross-stratified upperbeds (Fig. 2F). *Sinusichnus* burrows containing scattered dadocrinid ossicles were observed on the lower surfaces of some fallen blocks (Fig. 2E). The section ended with a cellular dedolomite, the Main Cellular Limestone (Emilówka Cellular Limestone Member; Kowal-Linka, 2009), which is the uppermost member of the Lower Gogolin Formation.

The horizon that yielded the new dadocrinid (Fig. 2) was measured in detail. Two metres below the base of the Emilówka Cellular Limestone, a 10-cm-thick, bioturbated limestone bed is overlain by 1 cm of marlstone and 10 cm marly limestones, which are sharply incised by erosional gutters containing isolated dadocrinid ossicles at the base of each (g in Fig. 2B, see also Fig. 2C). The gutter merged laterally into thin layers of wavy limestone with the articulated



and partly disarticulated crinoids described below (Fig. 2A); this is also the case at the lateral base of the gutter (x in Fig. 2C, detail in Fig. 2D).

The slab with dadocrinid remains from Żyglin was retrieved from the dump, but obviously like the Milowice material it came from the Wellenkalk Horizon. For descriptions of the Żyglin quarries, see Szulc (1991) and Szulc *et al.* (2009).

## MATERIALS

The Milowice material (MHI 1285) comprises two thin slabs of wavy limestone with juvenile and adult column and crown material MHI 1285/1 (Fig. 2A) and 1285/4, an isolated juvenile crown MHI 1285/3 (Figs 3D, 4), two polished sections of the lateral gutter cast MHI 1285/2 (Fig. 2C, D) and 1285/5, a firmground sample MHI 1285/7 (Fig. 2F), and a crinoidal limestone sample MHI 1285/8 (Fig. 2G). The Żyglin material (MHI 1289) is a bioturbated limestone with a 1–8 mm thin layer of crinoid columnal and crown material on top (Fig. 3E–I). For the purpose of comparison, additional material was studied: two juvenile individuals of *Dadocrinus* sp. from Gogolin (MHI 2184; Fig. 5A, B), a crown of *D. kunischi* (MHI 1284/1) from Gogolin, and a juvenile individual of *Carnallicrinus carnalli* (MLU.GP.2020.001) from the Schaumkalkbank Member of Jena Formation from Freyburg/Unstrut (Sachsen-Anhalt, Germany) (Fig. 5D).

### Repository of specimens

MHI - Muschelkalkmuseum Hagdorn Ingelfingen.  
MLU.GP - Martin-Luther-Universität Halle-Wittenberg,  
Geologisch-Paläontologische Sammlung.

## SYSTEMATIC PALAEOLOGY

(according to Hess and Messing, 2011)

Class Crinoidea Miller, 1821

Subclass Articulata Zittel, 1879

Family Dadocrinidae Lowenstam, 1942

**Type genus:** *Dadocrinus* von Meyer, 1847.

*Aszulcicrinus* new genus

**Type species:** *Aszulcicrinus pentebrachiatus* gen. et sp. nov, by monotypy.

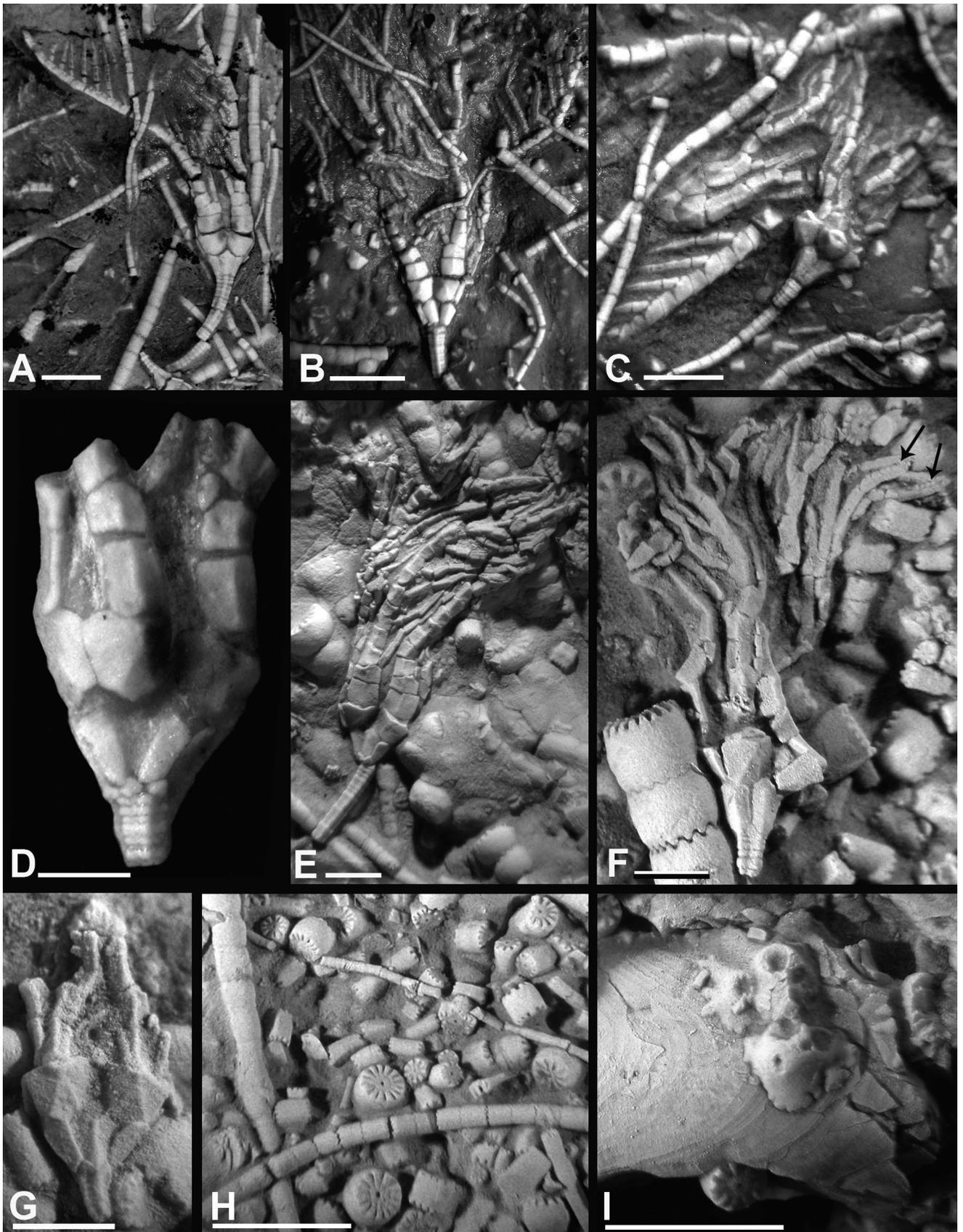
**Etymology:** In honour of the late Prof. Dr. Joachim (Achim) Szulc (1954–2020). [Pronunciation of the Polish spelling of the family name is: shoolt.s.]

**Diagnosis:** A small dadocrinid. Cup high conical, dicyclic or cryptodicyclic (infrabasals in juveniles mostly visible, in adult individuals concealed). Dorsal surfaces of basals, radials and proximal brachials of juvenile individuals keeled with keels above axial canals. Five unbranched uniserial arms. Proximal brachials of adult individuals dorsally almost even, medial and distal brachials V-shaped. First pinnule at second primibrachial. Pinnulars smooth, with granular platelets covering the food groove. Tegmen granulated. Column towards the basal circle becoming thicker, subpentalobate, distally increasingly circular, with more or less barrel-shaped columnals. Terminal column with discoid or incrusting holdfast.

**Remarks:** *Aszulcicrinus* differs from *Dadocrinus* and *Carnallicrinus* in its unbranched arms, devoid of an axillary second (primi)brachial. Instead, this brachial has one distal facet for the third brachial and a less wide facet for the first pinnule. The second primibrachials of *Dadocrinus* and *Carnallicrinus* are axillary, with two almost equally wide muscular facets for articulation with the first secundibrachials. The regularly unbranched arms of *Aszulcicrinus* are a unique character that has not been observed among other Encrinida. Single unbranched arms that occur rarely in individuals of *Encrinus liliiformis* are caused by traumatic loss and incomplete regeneration. As an alternative to the present opinion, Simms (pers. communication, 2011; see also Hagdorn, 2011, p. 96) suggested to interpret the unbranched arms as a secondary reduction from the primitive ten-armed stage, probably arising through pedomorphosis. However, this is not an individual but a regular character of both juveniles and adults within the fossil assemblages described here from Milowice and Żyglin and has not been observed among single individuals in *Dadocrinus* assemblages. Otherwise, early postlarval individuals of *D. kunischi* have axillary second primibrachials and hence 10 arms (Fig. 5A, B). A juvenile individual with axillary second primibrachials and the first pinnules at the second secundibrachial was figured by Jaekel (1918) and assigned to *D. kunischi* as “Jugendform” (juvenile in “Cyathocrinus stage”). Interpretation as regional ecophenotypic variation depending on water depth or flow regime is also excluded. As demonstrated by Dynowski and Nebelsick (2011) in *Encrinus liliiformis*, such variations should concern ornamentation of aboral brachial surfaces and arm lengths.

Unbranched arms are regarded as a diagnostic character, justifying the erection of the new genus *Aszulcicrinus*.

**Fig. 2.** Facies of Lower Gogolin Formation at type locality, abandoned quarry of Sosnowiec-Milowice, state of section in 1987. **A.** Upper side of wavy limestone slab MHI 1285/1 with holotype and paratypes. Scale 1 cm. **B.** Detail of finding horizon with gutter (g) incising into marly wavy limestones above firmground bed; the limestone bed with articulated crinoids (A) was taken from the right flank of the gutter. Scale 5 cm. **C.** Polished section of gutter (g in B) with dadocrinid sclerites; at right side transition into wavy limestone bed with articulated dadocrinids. MHI 1285/2. Scale 1 cm. **D.** Articulated crown of *Aszulcicrinus* at lower side of gutter (at x in Fig. C). Diameter of section 12 mm. **E.** *Sinusichnus* with scattered dadocrinid sclerites inside burrows at lower side of firmground. Handle of hammer 30 cm. **F.** Bioturbated firmground, above erosional surface thin sheet of isolated dadocrinid ossicles topped by hummocky cross stratified limestone. MHI 1285/7. Scale 1 cm. **G.** Surface of tempestitic crinoidal limestone with flat intraclasts; dadocrinid sclerites mostly abraded, pluricolumnal still articulated. MHI 1285/8. Scale 1 cm.



**Fig. 3.** *Aszulicrinus pentebrachiatus* nov. gen., nov. sp. from type locality Milowice (A–D) and Żyglin (E–I, whitened with ammonium chloride). **A.** Adult individual (holotype MHI 1285/1–1), note tapering of column below base, infrabasals concealed, first pinnule regularly at primibrachial 2 in the left arm, irregularly at primibrachial 3 in the right arm, widely spaced pinnules. Scale 5 mm. **B.** Adult individual (paratype MHI 1285/1–2), note pinnules alternating at higher brachial sides (enlarged in Figure C). Scale 5 mm. **C.** two juvenile individuals (paratypes MHI 1285/1–3, 1285/1–4), note keeled dorsal surfaces of radials and proximal primibrachials, high distal brachials

As proposed by Hagdorn (2011) the increase of arm number in Dadocrinidae from 5 in *Aszulcicrinus* to 10 in *Dadocrinus* and 20 in *Carnallicrinus* is interpreted as a phylogenetic trend towards optimization of the filter function. It is coincident with a general size increase and denser pinnulation, due to the increasingly biserial arrangement of the low cuneate brachials. The shape of the cup changes from high cone-shaped to bowl-shaped.

*Aszulcicrinus pentebrachiatus* new genus and species

Figs 2–4

1986 *Dadocrinus gracilis* (Buch) – Głuchowski, p. 182, pl. 1, figs 5–7 (partim)

1996 *Dadocrinus* sp. – Hagdorn, p. 22, pl. 2, fig. c.

2011 Dadocrinidae nov. gen. – Hagdorn, p. 96, figs 3, 6, 8a.

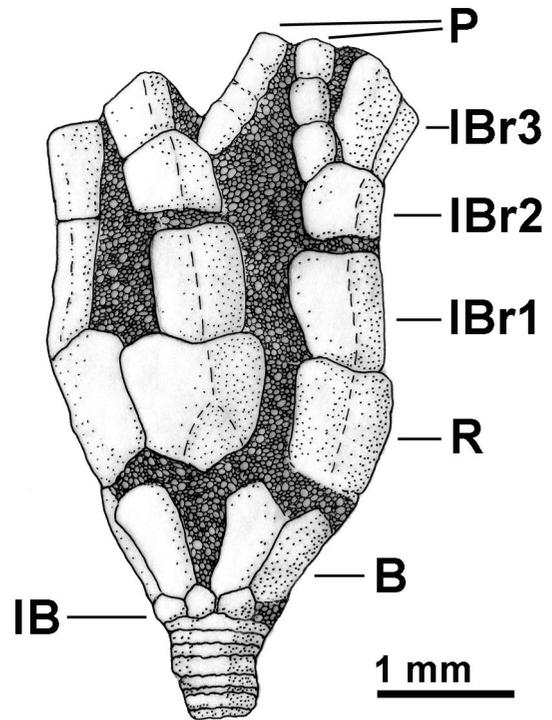
**Type material:** Holotype is the adult individual MHI 1285/1–1 of Figure 3A preserved on Muschelkalk slab MHI 1285/1 together with countless columns and additional crowns of different ontogenetic stages; among these the individuals MHI 1285/1–2–1285/1–5, and MHI 1285/3 are designated as paratypes (Fig. 3B–D), as well as MHI 1289/1–1–1289/1–3 from Żyglin (Fig. 3E–G).

**Etymology:** pentebrachiatus – with five arms. Greek: πέντε – five, βραχίον – arm (Latin: brachium – arm, branch).

**Material:** The Milowice (MHI 1285) and Żyglin (MHI 1289) material as indicated above. Besides the type series, these slabs contain additional, more or less well-preserved crowns and columns of juvenile and semiadult individuals.

**Diagnosis:** As for genus.

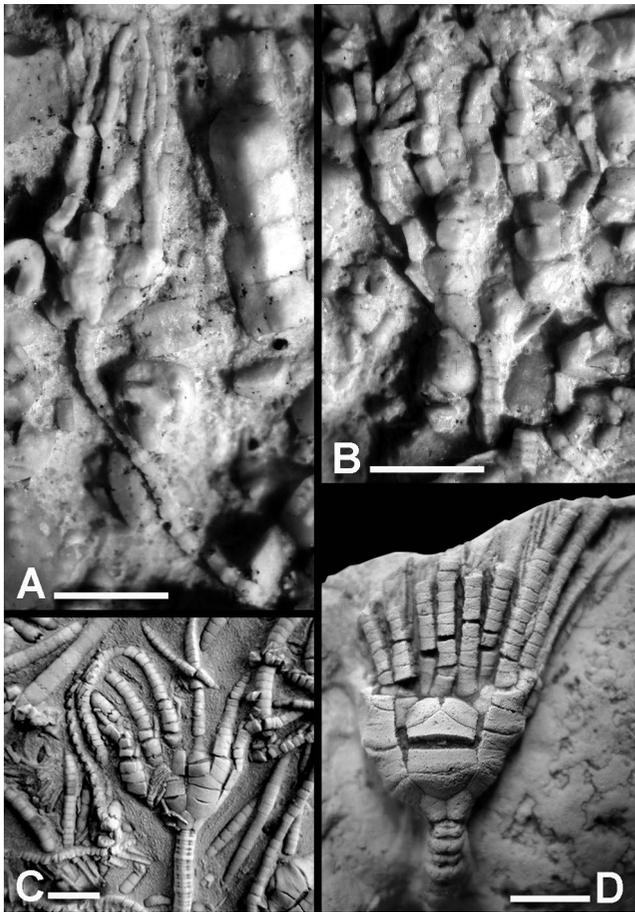
**Description:** The material under study comprises articulated crowns and columns of early post-larval to adult growth stages. The largest individual is the holotype with an overall crown length of 30.5 mm and at least 35 brachials in the longest arm measured (Fig. 3A). The crown of the smallest individual is 2.5 mm long and has only 4 brachials (Fig. 3G). The infrabasals that are visible in side view, up to a cup length of ca. 2.5 mm (dicyclic cup), have a wide base and insert with roof-shaped distal suture lines between the basals (Figs 3D–G, 4). In the cup of adult individuals the infrabasals are concealed (cryptodicyclic cup; Fig. 3A, B). The basals are more than twice as long as wide at their roof-shaped distal ends, which insert between the radials. Basals of juvenile individuals are dorsally keeled along the aboral nerve canal. Interbasal and basal-radial articulations are synostosial. The radials of adult individuals are equally long and wide, in juveniles slightly longer



**Fig. 4.** Camera lucida drawing of MHI 1285/3. Abbreviations: IB – infrabasals, B – basals, R – radials, IBr1 – first primibrachials, IBr2 – second (non-axillary) primibrachials, IBr3 – third primibrachial, P – pinnules.

than wide. Dorsally they are five-sided with the distal suture at the radial facet slightly emarginated (Figs 3D, 4). The triangular dorsal keels overlying the nerve canals are distinct in juveniles and disappear with increasing size (Figs 3D–F, 4). Interradial articulations are also synostosial. The radial facet is muscular with wing-shaped muscular attachments. The thin basal and radial plates enclose a relatively wide lumen. *Aszulcicrinus* has only five unbranched arms, hence, all brachials are primibrachials. Brachial number and width-length relation is changing with increasing size of individuals. In the smallest individuals representing the early post-larval pentacrinoïd ontogenetic stage, the first brachial is less than half as wide as the radial facet but comparatively long (Fig. 3G). Generally, the medial and distal brachials of juveniles are longer than wide and are dorsally keeled (Fig. 3C–G). In adults, the dorsal sides of proximal brachials become increasingly even and the medial and distal ones become V-shaped. The articulation of primibrachials 1 and 2

in zigzag-articulation. Scale 2 mm. **D.** Crown of isolated juvenile individual (paratype MHI 1285/3), note visible infrabasal circle, keeled dorsal surfaces of cup and arm ossicles. Scale 1 mm. **E.** Juvenile individual (paratype MHI 1289/1–1), note infrabasals visible, dorsally keeled brachials. Scale 2 mm. **F.** Juvenile individual (paratype MHI 1289/1–2), note granules covering food grooves of distal pinnules (arrows). Scale 1 mm. **G.** Early post-larval juvenile individual (paratype MHI 1289/1–3), note keeled basals and radials, narrow brachials. Scale 1 mm. **H.** Juvenile, semiadult, and adult columnals from surface of MHI 1289/1, note multiradiate articulation facets, straight and slightly inflated latera. Scale 5 mm. **I.** Cluster of seven discoid holdfasts at posterior end of *Bakevellia mytiloides* from surface of MHI 1289/1. Scale 5 mm.



**Fig. 5.** Arm branching in *Dadocrinus* and *Carnallicrinus*. **A, B.** Juvenile individuals of *D. kunischi*, Skala Marl Member of Lower Gogolin Formation, Gogolin (MHI 2184/1–1, 2184/1–2), arms branching at axillary primibrachials 2. Scale 2 mm. **C.** Adult individual of *D. kunischi*, Skala Marl Member of Lower Gogolin Formation, Gogolin-Zakrzów (MHI 1284/1), arms branching at axillary second primibrachials. Scale 5 mm. **D.** Juvenile individual of *C. carnalli* from Schaumkalkbank Member of Jena Formation, Schleberoda near Freyburg/Unstrut (MLU.GP 2020.001), arms branching at axillary second primibrachials and at axillary second secundibrachials. Scale 5 mm. C and D whitened with ammonium chloride.

is synostosomal. The articulation between primibrachials 2 and 3 was not clearly observable but is most likely muscular. Its dorsal side has not the typical shape of *Dadocrinus* axillaries with equal-sized roof-like facets for branching arms but an irregular outline with a relatively wider oblique facet for articulation with the next brachial and a clearly less wide smaller facet for the first pinnule (Fig. 3A, B). In the holotype, the arm on the right side in Fig. 3A is irregular with an additional, nonpinnulate primibrachial 2 and the first pinnule articulation to primibrachial 3. In juveniles, the brachials in medial and distal arms appear in zigzag arrangement because the articulation facets for the subsequent brachial and the facets for the first pinnulars are directed obliquely outward in opposite directions (Fig. 3C, F). Hence these brachials are distally wider than proximally. This zigzag arrangement disappears with increasing size. Brachials

of adult individuals are equally long and wide and have almost rectangular dorsal sides. The pinnules are inserted alternating at the right and the left side of subsequent brachials. Hence, in side view, the pinnulation appears wide-spaced (Fig. 3A–C). The first pinnular is slightly shorter than the following ones. The pinnulars are smooth with a food groove covered by small, granular sclerites (Fig. 3F). The coarser granulated tegmen is visible between the proximal arms in those individuals that are laterally compressed. Below the base, the column width decreases but reaches soon its constant thickness (Fig. 3A). In the proxistele, columnals are low and of subpentalobate outline with the nodals slightly wider and thicker. Towards the medial column internodals and nodals become equally sized and continuously circular (Fig. 3H). In juvenile individuals the entire column remains nearly subpentagonal. Circular columnals of adult individuals have straight latera; only among the largest columns distal columnals may have rounded epifacets or appear barrel shaped (Fig. 3E, F, H). The articulation facets are multiradiate with short and wide culmina; the circular central canal is relatively wide and surrounded by an elevated, finely granulated perilumen (Fig. 3H). The column terminates in a holdfast, formed by one single plate as an attachment disk. On even surfaces, it appears discoid, otherwise irregularly incrusting. Discoid holdfasts occur on hardgrounds and on posterior ends of mudsticking bivalves (Fig. 3I), incrusting holdfasts commonly on pluricolumnals of other individuals. Isolated *Aszulicrinus* columnals and holdfasts can hardly be discerned from *Dadocrinus* remains.

Like other dadocrinids, the benthic *Aszulicrinus* was attached by a holdfast, composed of a single attachment disk. Discoid holdfasts have been found in the Lower Gogolin Formation in Upper Silesia Upland on top of hardgrounds that are extensively bored with the boring trace *Trypanites* (Hagdorn, 1996, pl. 6a), but cannot be assigned to *Aszulicrinus* with certainty. The Żyglin slab (MHI 1289/1) preserves an individual of the mud sticking bivalve *Bakevella mytiloides* with a cluster of seven discoid holdfasts of juvenile *Aszulicrinus* close to its posterior end (Fig. 3I) and several holdfasts attached to distal columns of larger *Aszulicrinus* individuals. Hence, the attachment strategy of *Aszulicrinus* conforms to that of *Dadocrinus* as demonstrated by Hagdorn (1996). Under normal, fair-weather conditions, the small-sized dadocrinids were sufficiently anchored by mud sticking bivalves or by larger individuals in muddy environments, where lithified sediment was not available. During storms reaching the sea bottom, they were uprooted, transported, and subsequently embedded in re-sedimenting mud on depositional surfaces (bedding planes) or at the bases of storm-induced gutters, as preserved at Milowice. This preservation is a typical obrutational echinoderm conservation lagerstätte, whereas the thicker crinoidal limestones with disarticulated ossicles predominating in the downsection Zakrzów Crinoidal Limestone Member represent a concentration lagerstätte (Seilacher, 1970; Hagdorn, in press).

All individuals preserved on slabs MHI 1285/1 and 1289/1 are embedded in “shaving brush posture” (Baumiller *et al.*, 2008). Due to pressure from sediment load, in many specimens the plates of the cups are laterally more or less

displaced (e.g., Figs 3B, D–F, 4) because of the synostial articulations of the thin plates. The gaps between single arms are most distinct in juvenile individuals, the first primibrachials of which are narrower than the radial facet, and may reveal the terminal plating (e.g., in Fig 3B).

**Remarks:** As for genus.

**Type locality:** Abandoned quarry of Sosnowiec-Milowice (województwo śląskie, Poland), next to a historical limekiln.

**Type level:** Thin wavy limestone bed within Wellenkalk Horizon of Lower Gogolin Formation (Fig. 2B).

**Stratigraphic distribution:** Wellenkalk Horizon of Lower Gogolin Formation; *Dadocrinus* biozone, Middle Triassic (early Anisian).

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