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CRINOIDS (CRINOIDEA, ECHINODERMATA) FROM THE MIDDLE JURASSIC (CALLOVIAN) OF EASTERN POLAND: A CASE STUDY FROM THE ŻEBRAK IG 1 BOREHOLE

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Abstract: A taxonomic account of the Callovian crinoid fauna from the Żebrak IG 1 borehole (eastern Poland) is presented. The assemblage contains numerous isocrinid ossicles (Isocrinidae) assigned to the following taxa: *Isocrinus* cf. *nicoleti* (Desor), *Isocrinus* sp., *Chariocrinus andreae* (Desor), *Balanocrinus* cf. *subteres* (Münster in Goldfuss) and *Pentacrinites* sp. These isocrinids are associated with a few ossicles of cyrtocrinids (Cyrtocrinida; Cyrtocrinida indet.). The crinoid remains are poorly preserved; they all are isolated ossicles, showing broken margins and/or abraded surfaces. Such a state of preservation documents a long distance of transportation and/or re-deposition in a high-energy, shallow-water setting. The crinoid assemblage differs significantly from those of southern Poland (the Polish Jura Chain and the Mesozoic margin of the Holy Cross Mountains), in which sessile crinoids, such as cyrtocrinids (Cyrtocrinida), inhabiting mostly deeper-water carbonate facies, are predominant.

Key words: Echinoderms, crinoids, Jurassic, Callovian, Poland.

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INTRODUCTION

Jurassic crinoids (Crinoidea) from southern Poland (Polish Jura Chain, Mesozoic margin of the Holy Cross Mountains, Pieniny Klippen Belt, and Tatra Mountains) have been the subject of many studies (e.g., Roemer, 1870; Wójcik, 1910; Różycki, 1953; Dayczak-Calikowska, 1980; Głuchowski, 1987; Salamon and Zatoń, 2006, 2007; Salamon, 2008a; Boczarowski, 2012). As well, very little is known about crinoids from central and eastern Poland: Salamon (2008b) documented a highly diversified crinoid fauna from the Callovian clay deposits of the Łuków glacial drift. It should be kept in mind that these Jurassic sediments at Łuków are not autochthonous; they were probably scoured from the bottom of the Baltic Sea by glaciation (e.g., Olempska and Błaszyk, 2001). The same applies to the Tithonian-Berriasian forms from Kruhel Wielki in south-eastern Poland: Hess *et al*. (2011) identified a rich assemblage of cyrtocrinids (Cyrtocrinida), associated with comatulids (Comatulida) and isocrinids (Isocrinida). Likewise, with the deposits of Łuków, those of Kruhel were transported most probably from the south or southwest (details in Hess *et al*., 2011 and literature included). Radwańska and Radwański (2003) described cyclocrinids from the Oxfordian of the Kuyavia area in central Poland. The authors also mentioned the occurrence of these crinoids in the Callovian strata of southern Poland.

The present account is the first report of crinoids from *in situ* sediments of eastern Poland. It includes 1) a description of the crinoid assemblage from the Żebrak IG 1 borehole, 2) a comparison of it with all Callovian crinoid assemblages from different regions in Poland and the adjacent eastern countries, and 3) a brief discussion of the taphonomy, palaeoecology and paleobiogeography of the crinoids.

GEOLOGICAL SETTING

The Żebrak IG 1 borehole (52°04′26.86″ 22°05′47.18″) is located in the eastern part of the Polish Lowlands, within the Mazury-Podlasie Monocline (Fig. 1; Narkiewicz and Dadlez, 2008; Żelaźniewicz *et al*., 2011), this latter being the western part of the Eastern European Platform (Aleksand-

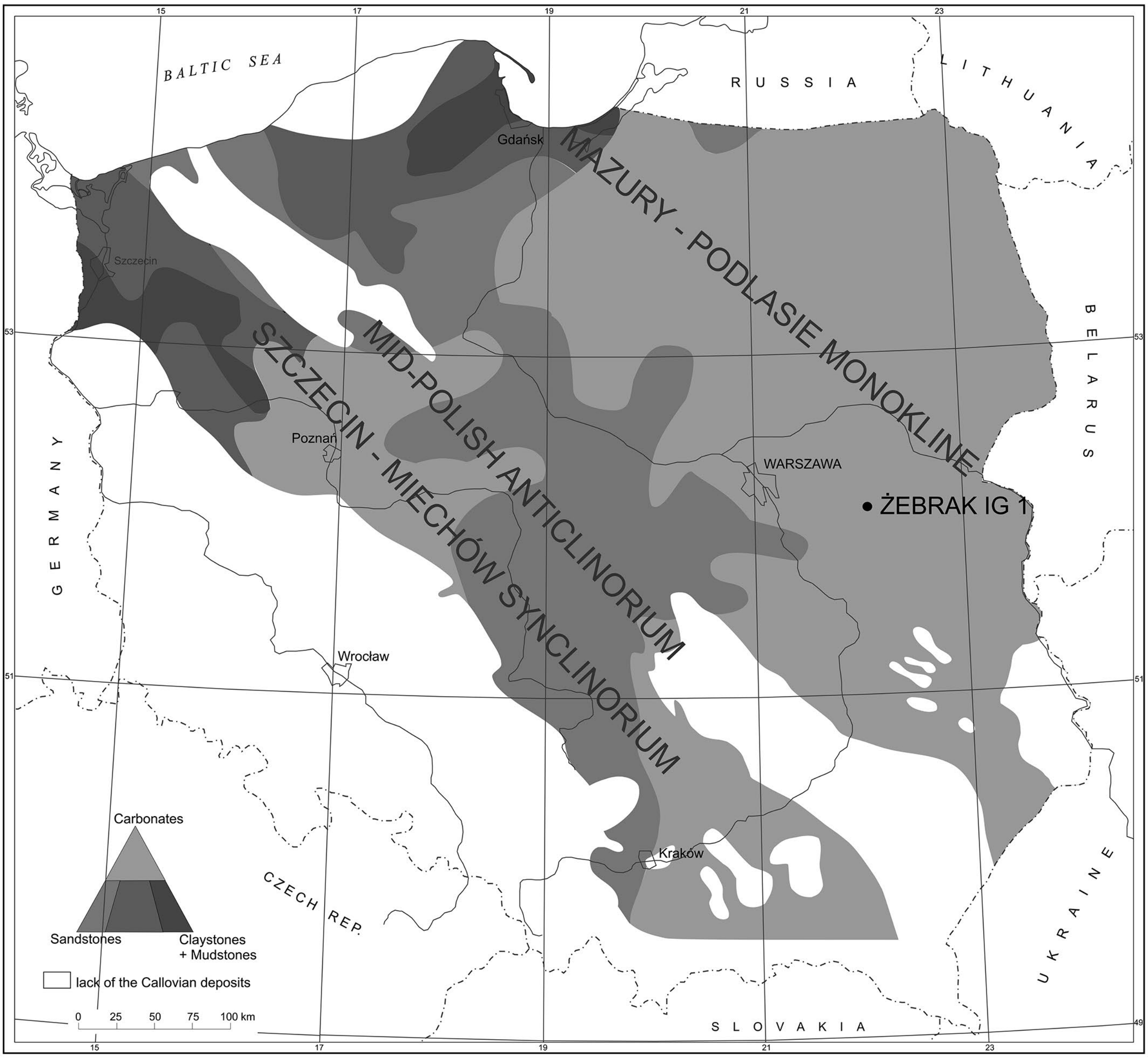

Fig. 1. Location of the Żebrak IG 1 borehole on a map of Callovian lithofacies (from Dayczak-Calikowska and Moryc, 1988).

rowski, 2017). There the Middle Jurassic deposits directly overlie the Upper Rhaetian (Upper Triassic; Fig. 2). At their base lies a 40-cm-thick bed of sandy-carbonate conglomerates, with limonitized pebbles of carbonate sandstones within a sandy-carbonaceous matrix (Niemczycka, 1975). There is a 38.5-m-thick set of crinoidal limestones higher in the section, displaying creamy, rusty, brownish and greyish colours. Along with the dominant crinoids are also numerous echinoid fragments, corals, bivalves, brachiopods and scarce sponge spicules (Radlicz, 1975). Quartz grains, iron oxides and hydroxides are noteworthy constituents in this interval. Worth mentioning also is the size variation of the detrital grains observed: ranging from fine- to even coarser-grained intercalations.

Marked fragmentation of organic elements indicates shallow-marine, strongly turbulent conditions of sedimentation. The environment was highly oxygenated, in marginal-marine conditions, with a high content of iron compounds, supplied from neighbouring land masses to the middle or internal carbonate ramp.

The chronostratigraphy of the deposits studied is based on isolated records of index microfossils. From the upper part of the basal conglomerate J. Smoleń noted the ostracod *Progonocythere* cf. *convexa* Błaszyk, known from

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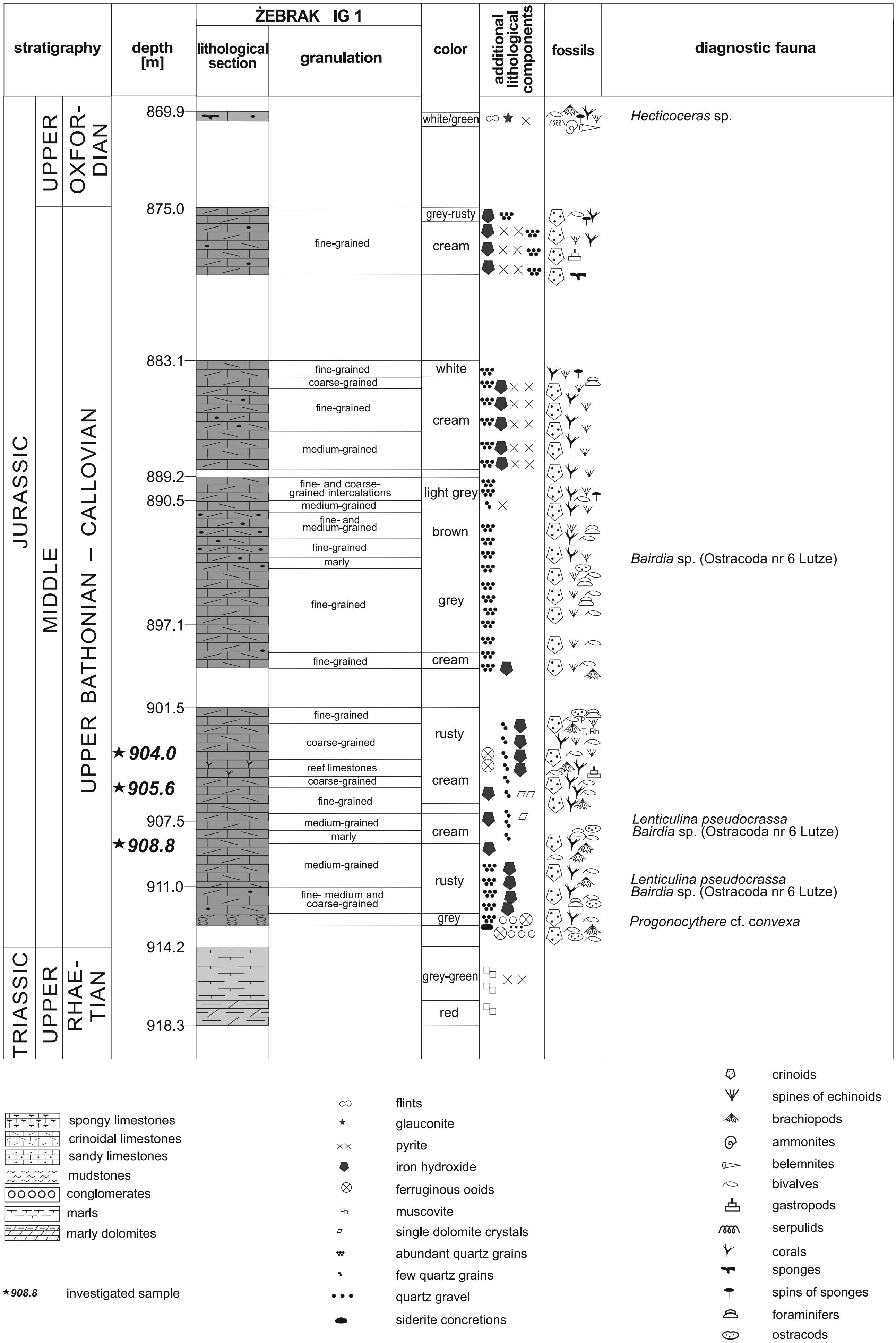
Fig. 2. The Żebrak IG 1 borehole section of upper Bathonian – Callovian deposits (lithology from Niemczycka, 1975 and Bielecka, 1975; petrography from Radlicz, 1975) with location of samples and major macrofauna and microfauna (identification by: Znosko in Niemczycka, 1975, and Smoleń, unpubl. data, respectively).



ŻEBRAK IG 1
stratigraphy
depth [m]
lithological section
granulation
color
additional lithological components
fossils
diagnostic fauna
JURASSIC
UPPER
OXFOR-DIAN
MIDDLE
UPPER BATHONIAN – CALLOVIAN
TRIASSIC
UPPER
RHAE-TIAN
869.9
875.0
883.1
889.2
890.5
897.1
901.5
★904.0
★905.6
907.5
★908.8
911.0
914.2
918.3
fine-grained
fine-grained
coarse-grained
fine-grained
medium-grained
fine- and coarse-grained intercalations
medium-grained
fine- and medium-grained
fine-grained
marly
fine-grained
fine-grained
fine-grained
coarse-grained
reef limestones
coarse-grained
fine-grained
medium-grained
marly
medium-grained
fine- medium and coarse-grained
white/green
grey-rusty
cream
white
cream
light grey
brown
grey
cream
rusty
cream
cream
rusty
grey
grey-green
red
P
T, Rh
Hecticoceras sp.
Bairdia sp. (Ostracoda nr 6 Lutze)
Lenticulina pseudocrassa
Bairdia sp. (Ostracoda nr 6 Lutze)
Lenticulina pseudocrassa
Bairdia sp. (Ostracoda nr 6 Lutze)
Progonocythere cf. convexa
spongy limestones
crinoidal limestones
sandy limestones
mudstones
conglomerates
marls
marly dolomites
★908.8 investigated sample
flints
glauconite
pyrite
iron hydroxide
ferruginous ooids
muscovite
single dolomite crystals
abundant quartz grains
few quartz grains
quartz gravel
siderite concretions
crinoids
spines of echinoids
brachiopods
ammonites
belemnites
bivalves
gastropods
serpulids
corals
sponges
spins of sponges
foraminifers
ostracods

the Upper Bajocian – Bathonian of Poland (Bielecka *et al*., 1980a). In the higher part of the crinoid limestones, Bielecka (1975) identified the foraminifer *Lenticulina* cf. *pseudocrassa* (Mjatliuk) (depth 911.0 m; 908.7 m), characteristic for the Callovian (Bielecka *et al*., 1980b; Smoleń, 2000), and the ostracod *Bairdia* sp. (Ostracoda nr 6 Lutze, 1960) at depths of 911.0 m; 908.7 m and 893.0 m. The latter already had been recorded in the Variansmergel Formation of Germany (Middle to Upper Bathonian) and from the Middle Callovian (*jason* Zone) (Lutze, 1960).

The Middle Jurassic microfauna recorded from the deep boreholes of eastern Poland (Podlasie and Lublin areas) is also consistent with a Bathonian and/or Callovian age (Niemczycka, 1965, 1979, 1989). The regional distribution patterns of the Middle Jurassic sedimentary facies of the Polish Lowlands indicate that the marine transgression covered part of the Mazury-Podlasie area during the Middle Bathonian and their complete submergence occurred in the Late Bathonian (Dayczak-Calikowska and Moryc, 1988; Dayczak-Calikowska, 1997; Feldman-Olszewska, 1998; Pieńkowski *et al*., 2008). In this respect, the Middle Jurassic deposits of the Żebrak IG 1 borehole are representative for a broader area (Niemczycka, 1978, 1979; Feldman-Olszewska, 2007, 2008, 2011a, b).

MATERIAL AND METHODS

Three core samples, taken at different depths in the Żebrak IG 1 borehole (908.8 m, 905.6 m, and 904 m; weighting 383 g, 481 g, and 282 g respectively), constitute the basis of the present study. At first, every surface of the samples was observed under a binocular microscope. Numerous disarticulated echinoderm ossicles were then noticed (Fig. 3L). Among them, abraded crinoid cirrals and incomplete columnals were the most abundant. Some isolated, abraded plates of regular echinoids also were observed (Fig. 3A). In addition to the echinoderm remains, gastropods, ostracods and bivalves were seen.

These fossiliferous core samples subsequently were treated with Glauber's salt. Samples were repeatedly (six times) frozen and thawed, and after resting they were washed and sieved, using a 1.0 mm, 0.5 mm, 0.315 mm and 0.1 mm mesh-size column. The residues then were dried at 140°C and all the echinoderm material was picked out under the binocular microscope. As a result, a few thousands of echinoderm ossicles were retrieved. Most of them are fragmented and poorly preserved. The most abundant are compressed, ellipsoidal and rhomboidal cirrals, characteristic of *Pentacrinites* sp., and/or *Isocrinus* cf. *nicoleti* (Desor) (see discussion below), partly preserved columnals, and strongly abraded, small cirrals, circular in outline, assignable to *Isocrinus* sp. Other documented columnals belong to the taxa *Pentacrinites* sp., *Chariocrinus andreae* (Desor), *Balanocrinus* cf. *subteres* (Münster in Goldfuss), and Cyrtocrinida indet.

The material retrieved is housed at the Faculty of Earth Sciences, University of Silesia, Sosnowiec, under catalogue number GIUS 8–3678/1–6.

SYSTEMATIC PALAEONTOLOGY

Systematics of Jurassic crinoids follows the scheme elaborated by Hess and Messing (2011).

Order Isocrinida Sieverts-Doreck in Moore, Lalicker and Fischer, 1952

Suborder Isocrinina Sieverts-Doreck in Ubaghs, 1953

Family Isocrinidae Gislén, 1924

Subfamily Isocrininae Gislén, 1924

Genus *Isocrinus* von Meyer in Agassiz, 1836

Type species: *Isocrinites pendulus* von Meyer in Agassiz, 1836.

Isocrinus cf. *nicoleti* (Desor, 1845)
Fig. 3D

Material: 9 incomplete internodals. GIUS 8–3678/1.
Description: The distal internodals are sub-stellate in outline. The most proximal internodals are larger and stellate in outline. Some small columnals have the distinct facet pattern typical of *I. nicoleti* that is pentalobate? and with fairly sharp interradii. The crenularium consists of numerous thin crenulae: up to about 28 crenulae on each petal. In the radial part, adjacent crenulae almost touch each other. The petal floors are elongated. The latera is smooth. The lumen is small and circular.
Discussion: It has been stressed repeatedly that the columnal facet of *I. nicoleti* is particularly characteristic for the species and not to be confused with any other isocrinid species (e.g., Salamon and Zatoń, 2007; Salamon, 2008a). It is noteworthy that stellate or sub-stellate columnals co-occur with smaller pentalobate or pentagonal columnals, which in the present account are also assigned to *Isocrinus* cf. *nicoleti*. However, the shape and facet ornamentation of the latter columnals are quite unusual for Middle Jurassic isocrinids. On the other hand, Głuchowski (1987) illustrated similar columnals that were assigned to *I. nicoleti* (see pl. 27, figs 1, 3, 4 in Głuchowski, 1987). Furthermore, Klikushin (1992) assigned Callovian columnals, displaying similar morphology, to *Isocrinus desori* (Thurmann in Thurmann and Étallon). It seems, however, that the columnals described by Klikushin (1992) should be linked to *I. nicoleti* (see discussion in Salamon, 2008a, pp. 139–140).
Range: Middle Jurassic (Aalenian–Callovian) of Asia, Europe and Northern America.

Isocrinus sp.
Fig. 3C, G

Material: 30 incomplete, abraded internodals and nodals; few abraded cirrals. GIUS 8–3678/2.
Description: The columnals are fragmented, so their original outline is difficult to assess. As well, the internodals are pentalobate and/or sub-pentalobate, whereas the nodals are stellate, sub-stellate and sub-pentalobate. The internodals and nodals are almost equal in diameter, but the nodals are

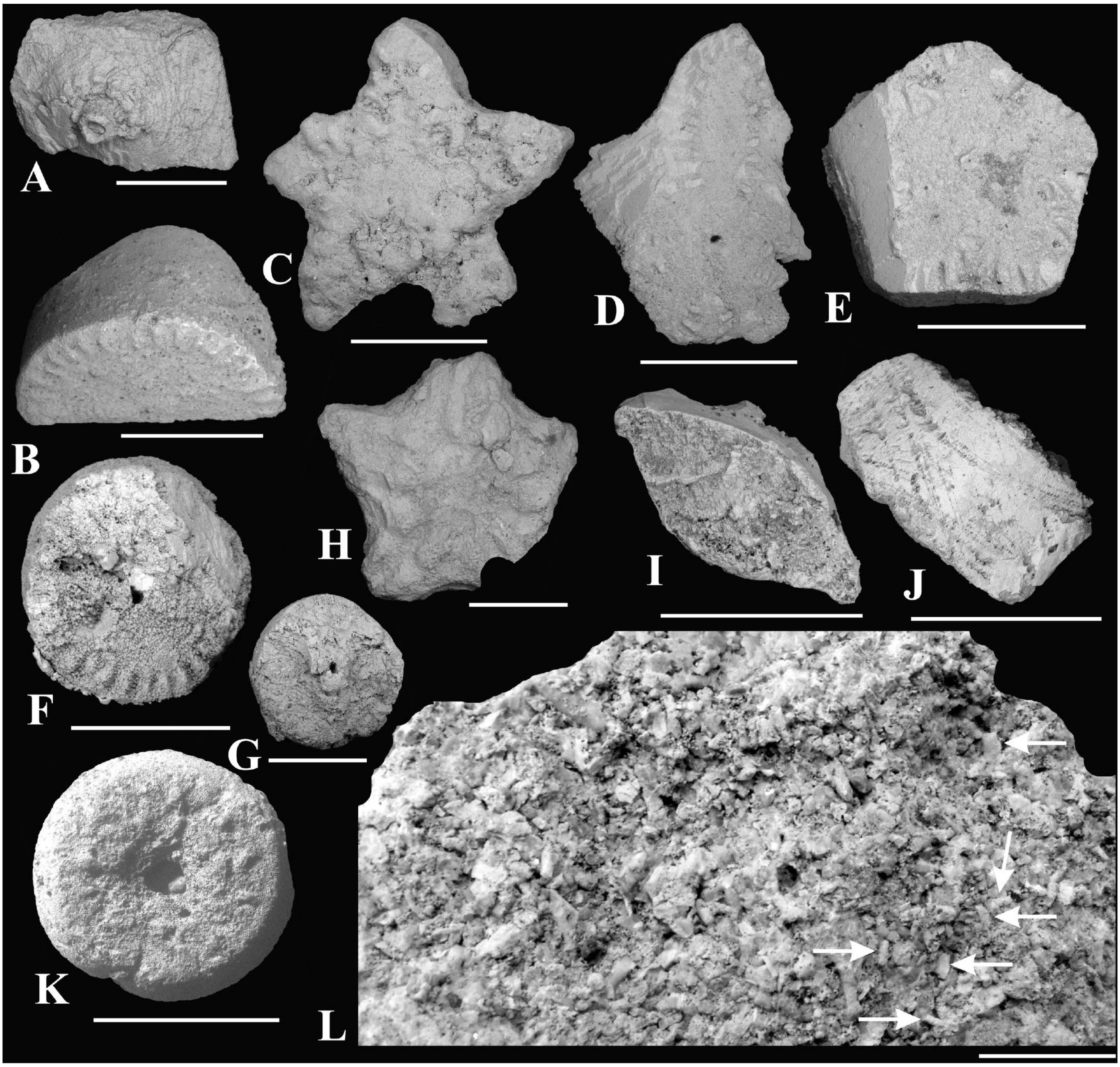


Fig. 3. Callovian echinoderms from the Żebrak IG 1 borehole. Scale bar equals 1 mm, except L: 10 mm. GIUS 8-3678/1-6. **A**. echinoid test plate. **B**, **F**. *Balanocrinus* cf. *subteres*, articular face (B – adult, F – juvenile specimens, respectively). **C**, **G**. *Isocrinus* sp., articular face and cirral face. Please note that the cirral may belong to another isocrinid or comatulid. **D**. *Isocrinus* cf. *nicoleti*, articular face. **E**. *Chariocrinus andreae*, articular face. **H–J**. *Pentacrinites* sp.; H – columnal articular face, I – cirral articular face, J. – cirral latera. **K**. Cyrtocrinida indet., articular face. **L**. slab showing disarticulated and/or crushed echinoderm remains. Arrows indicate cirrals of *Pentacrinites* sp.

higher. The petal floors are elongated or lanceolate. Every petal is surrounded by a maximum of 18 crenulae. The latera of internodal columnals are smooth, sometimes covered with blunt-keel. The cirral scars are small and display a depressed elliptical outline. They are directed outwards. The lumen is small and circular, usually hardly visible. The cirrals are small but long, and circular in outline. The lumen is rather large and circular, surrounded by a distinct perilumen.

Discussion: It is likely that some of ossicles assigned to *Isocrinus* sp. may actually belong to *I. pendulus* (von Meyer), commonly occurring in the Callovian of Łuków (eastern Poland) and Papilė (Lithuania). Columnals from these localities are pentalobate to stellate in outline and display elongated petal floors. However, Salamon (2008b) pointed out that the columnals of *Isocrinus pendulus* possess 21 or 22 crenulae per petal, whereas the columnals described here have up to 18 crenulae per petal. It cannot be also excluded that the cirrals assigned here to *Isocrinus* sp. may belong to *Balanocrinus*, *Chariocrinus*, or even to comatulids that are also known from the Callovian of Łuków and Papilė.

Range: Upper Triassic (Carnian?)–Lower Cretaceous (Albian) of Asia and Europe.

Genus *Chariocrinus* Hess, 1972

Type species: *Isocrinus andreae* Desor, 1845.

Chariocrinus andreae (Desor, 1845)
Fig. 3E

* 1845 *Chariocrinus andreae* – Desor, p. 213.

1879 *Cainocrinus andreae* (Desor) – de Loriol, p. 112, pl. 14, figs 31–38.

1972 Chariocrinus andreae (Desor) – Hess, p. 197, figs 15–20, 22

Material: 40 incomplete internodals. GIUS 8-3678/3.
Description: The columnals are pentagonal, pentalobate and stellate in outline. The columnal facet is covered with a rather distinctive pattern. The petal floors are elongated with a clearly visible crenularium, consisting of up to 16 crenulae. Every petal floor is surrounded by a maximum of 12 marginal crenulae. The latera is smooth. The lumen is small.
Discussion: *Chariocrinus andreae* is the most common species, occurring in the Middle Jurassic clays of Poland. In southern Poland, this species occurs in the Bathonian black and grey clays of the Cracow-Częstochowa Upland. In eastern Poland and Lithuania (respectively Łuków and Papilė localities), it was recorded from Callovian clays.Salamon and Zatoń (2007) mentioned a single columnal of *C. andreae* from the Callovian carbonate facies of Polish Jura Chain.
Range: Middle Jurassic (Aalenian–Callovian) of Antarctica, Europe and Northern America (Greenland).

Subfamily Balanocrininae Roux, 1981
Genus *Balanocrinus* Agassiz in Desor, 1845

Type species: *Pentacrinites subteres* Münster in Goldfuss, 1826.

Balanocrinus cf. *subteres* (Münster in Goldfuss, 1826)
Fig. 3B, F

Material: 4 internodals. GIUS 8–3678/4.
Description: The columnals are circular in outline. The columnal facet is covered with large and triangular petal floors. In juvenile specimens, these petals are not well developed. The petal floors are separated from each other by adradial crenulae belts, consisting of two parallel sets of minute tubercles. Every petal floor is surrounded by up to 8 marginal crenulae. The latera is smooth or slightly convex. The lumen is rather small and circular.
Discussion: Apparently, *B. subteres* is the best-known isocrinid species found in the Mesozoic sediments of the northern hemisphere, with the widest spatial and temporal distribution. This, however, may be related to the fact that this species is only known from isolated ossicles. It is highly probable that some examples of this species from the Triassic, Lower Jurassic and Cretaceous (review in Klikushin, 1992) are referable to other balanocrinid species, or even to another genus (*Isocrinus*). This fact was a reason for including the present materials in *Balanocrinus* cf. *subteres*. It should be noted that the stems of the various isocrinid species may be similar to each other, both in terms of shape and facet morphology. For instance, *Balanocrinus berchteni* Hess and Pugin, *B. gillieroni* (de Loriol), *B. hessi* Salamon and Zatoń, *B. pentagonalis* (Goldfuss) recorded from Poland are very similar to *B. subteres* (compare e.g., Głuchowski, 1987; Salamon, 2008a, b; Salamon and Zatoń, 2007; Zatoń *et al*., 2008; Gorzelak and Salamon, 2009; Salamon and Gorzelak, 2010). Until complete (or nearly complete, or connected cup elements; Hess, 2014) skeletons of these species are found (cf. balanocrinids, described by Simms, 1989), assignment of circular columnals covered with triangular petal floors should be treated as provisional.
Range: Upper Triassic?, Lower?–Upper Jurassic (Sinemurian?–Tithonian) of Africa, Asia, Europe and Northern America.

Suborder Pentacrinitina Gray, 1842
Family Pentacrinitidae Gray, 1842
Genus *Pentacrinites* Blumenbach, 1804

Type species: *Pentacrinites fossilis* Blumenbach, 1804.

Pentacrinites sp.
Fig. 3H, I, J, L

Material: 40 partly preserved and dozens of complete cirrals; 7 incomplete abraded internodals and nodals. GIUS 8–3678/5.
Description: The internodals are penta-stellate and pentagonal? in outline. The nodals are larger than the internodals. They are presumably stellate in outline. The edges of the columnals are bent. The petal floors are long and narrow, in some cases drop-like. They are marked by symmetric depressions. The crenularium is faintly preserved. The latera of internodals is smooth, rarely uneven or ornamented with rounded longitudinal carinae. The cirral scars are small and directed outwards or slightly upwards. In some cases, cirral scars are alternately offset to the right side or the left side of the radii. The perilumen occurs around a relatively large and circular lumen. The cirrals are compressed, ellipsoidal or rhomboidal in outline. The cirral articular surface may be covered with a distinct fulcral ridge.
Discussion: Salamon (2008a) stressed that assignation of isolated ellipsoidal or rhomboidal cirrals, not associated with any stem or crown parts, to *P. dargniesi* is uncertain: because cirrals of other isocrinid species (e.g., *I. nicoleti)* are comparable in size and shape (see pl. 28, figs 3–5 in Głuchowski, 1987). This is why the authors decided to classify the present material as *Pentacrinites* sp. It also cannot be excluded that some of the cirrals documented here may belong to *I.* cf. *nicoleti.*
Range: Lower-Middle Jurassic (Toarcian–Callovian) of Europe.

Order Cyrtocrinida Sieverts-Doreck in Moore, Lalicker and Fischer, 1952

Cyrtocrinida indet.
Fig. 3K

Material: 1 almost complete but abraded columnal and few fragmentarily preserved columnals. GIUS 8-3678/6.
Description: The columnals are circular in outline, barrel-shaped. The facet is covered with circular, regular granulae? and/or crenulae. The latera is smooth or covered with tubercles. The lumen is rounded and relatively large.
Discussion: The shape and ornamentation of the columnal facet described herein are similar to those observed in sclerocrinids (Sclerocrinidae) that recently were reported from the Callovian and Oxfordian strata of extra-Carpathian Poland (e.g., text-fig. 4i in Salamon, 2008c). Similar small columnals with short crenulae and relatively large and circular lumen from the Bathonian of Polish Jura Chain were assigned by Salamon and Zatoń (2007) to Millericrinina (IInd morphotype of Millericrinina, according to these authors). However, it seems probable that these columnals actually may belong to cyrtocrinids.
Range: Triassic (Rhaetian?), Lower Jurassic (Sinemurian) – Recent.

DISCUSSION

General remarks on crinoids occurrence and palaeoecology

Five isocrinid taxa from the Żebrak IG 1 borehole samples are identified: *Balanocrinus* cf. *subteres, Chariocrinus andreae, Isocrinus* cf. *nicoleti, Isocrinus* sp., and *Pentacrinites* sp. (Tab. 1). Such a taxonomical composition possibly reflects the peculiar sedimentary environment; from the high degree of oxidation and the indicated record of significant turbulence, this must have been a shallow-marine area. This is supported by the almost total absence of cyrtocrinids; according to Hess *et al*. (2011) cyrtocrinids could indicate a depth of over 100 m. However. most of species listed here were also found in cross-bedded ooid limestones of Switzerland (Swiss Jura; Hess, 1999b), from a high-turbulence environment, as in eastern Poland.

Deposits with *Chariocrinus andreae* were considered by Hess (1999b) as representing large sand dunes at the margins of large fields of sand-wave complexes, with crinoids standing against the current in depressions that were leeward with respect to the backward parts of dunes. On the other hand, *P. dargniesi* is interpreted as a pseudo-planktonic form, transported from the open sea on the lower surfaces of driftwood fragments (Simms, 1999). Possibly particular specimens were connected to each other by long cirri and formed mats, free-floating along the bottom (Klikushin, 1992; Hess, 1999a; Seilacher and Hauff, 2004). *Isocrinus nicoleti* was reported from both ooid shoals of the carbonate shelf and slightly deeper environments, represented by intercalating marls and bioclastic limestones (Hess, 1999b; Gonzalez and Wetzel, 1996). *Balanocrinus* settled on the hardgrounds, but it can also be found in mudstone-dominated settings, possibly on local elevations of the fine-grained bottom (Hess, 2014). *Balanocrinus subteres*, the largest species of the genus, was reported from bottom elevations, not far below the storm wave-base (Hess and Spichiger, 2001) where these long crinoids could both find enough food and benefit from the oxygenated water levels (Hess, 2014).

Remarks on crinoid taphonomy

Crinoids from the Żebrak IG 1 borehole are only represented by isolated ossicles. No articulated elements, such as pluri-columnals or pluri-cirrals, were documented. Furthermore, these ossicles are highly abraded and commonly display broken and/or rounded margins. Some ossicles reveal post-diagenetic fracturing, step-like surfaces and wear scars. A similar state of preservation was observed in the associated echinoids, molluscs and ostracods. Furthermore, there is clear evidence of a taphonomic sorting of echinoderm ossicles (e.g., no brachials found). Overall, such a state of preservation is characteristic of mechanical abrasion, due to a long distance of transportation and/or reworking before final burial under high-energy, shallow-sea conditions (cf., Gorzelak and Salamon, 2013). The presence of crinoid remains capping by autotomy of the animals' distal columns, caused by accumulations is not taken under consideration here, owing to the strong degree of echinoderm abrasion.

Diversity of Callovian crinoids in Poland and Eastern Europe

Only six isocrinid taxa, *Balanocrinus hessi* Salamon and Zatoń, *B. pentagonalis* (Goldfuss), *B. subteres*, *Chariocrinus andreae*, *Pentacrinites dargniesi* and *Isocrinus*? *cingulatus*?, are known from the Callovian of the Polish Jura Chain and the Holy Cross Mountains margin (Salamon, 2008c). Among them, three species (*B. subteres, C. andreae, P. dargniesi*) are also recorded from eastern Poland. Apart from isocrinids, millericrinids - Millericrinina: two different morphotypes and cyclocrinid (Cyclocrinida): *Cyclocrinus macrocephalus* (Quenstedt) - were recorded from the Polish Jura Chain (Salamon and Zatoń, 2007), but are unknown from eastern Poland. The number of isocrinid species in the Callovian of the Polish Jura Chain could be a little higher. Roemer (1870), Siemiradzki (1903) and Dayczak-Calikowska (1980) mentioned the occurrence of seven crinoid species in southern Poland: cyclocrinids, millericrinids and five isocrinid species [*Balanocrinus pentagonalis*, *B*. aff. *subteroides* (Quenstedt), *Isocrinus*? *cingulatus* (Münster in Goldfuss), *Isocrinus*? *nodosus* (Quenstedt), *Pentacrinus cristagalli* (Thurmann in Thurmann and Étallon)] were documented. The presence of cyclocrinids, millericrinids and *B. pentagonalis* in these sediments was confirmed by Salamon and Zatoń (2007) and Salamon (2008c). *Isocrinus*? *nodosus* is a common species in the Bajocian-Bathonian of Europe and Asia; consequently, the occurrence of it in the Callovian is doubtful. Likewise, *Pentacrinus cristagalli*, synonymous with *Isocrinus desori* (Thurmann in Thurmann and Étallon), is indicative of the lower Oxfordian (Klikushin, 1992). *Balanocrinus subteroides*, in turn, commonly

Table 1

List of Callovian crinoids reported from extra-Carpathian Poland.

	Isocrinids	Cyrtocrinids	Comatulids	Millericrinids
Southern Poland (Polish Jura Chain and Holy Cross Mountains)	*Balanocrinus hessi* *B. pentagonalis* *B. subteres* *Chariocrinus andreae* *Isocrinus*? *cingulatus*? *Pentacrinites dargniesi*	*Cyrtocrinus* sp. *Dolichocrinus aberrans* *Fischericrinus ausichi* *Hemicrinus* sp. *Lonchocrinus dumortieri* *Phyllocrinus* sp. *P. belbekensis* *P. stellaris* *Pilocrinus moussoni* *Remisovicrinus polonicus* *R.* aff. *polonicus* *Sclerocrinus* sp. *Tetracrinus moniliformis* Cyrtocrinina		*Cyclocrinus macrocephalus* Millericrinina
Eastern Poland (Łuków Clay)	*Balanocrinus* sp. *B. berchteni* *B. pentagonalis* *B. subteres* *C. andreae* *Isocrinus* sp. *I. nicoleti* *I. pendulus* *P.* cf. *dargniesi*		*Palaeocomaster* sp. Paracomatulidae sp. et gen. indet.	
Eastern Poland (Żebrak IG 1 borehole)	*B.* cf. *subteres* *Ch. andreae* *Isocrinus* sp. *I.* cf. *nicoleti* *P.* sp.	Cyrtocrinida indet.		

occurs in the Lower Jurassic of Europe and Asia (Simms, 1989; Klikushin, 1992). The only other isocrinid species, possibly present in the Callovian of Polish Jura Chain and Holy Cross Mountains, is *Isocrinus*? *cingulatus*, known from Europe and Russia (Quenstedt, 1851; Loriol, 1889; Woodward, 1894; Głuchowski, 1987). The most important difference in the taxonomic composition of crinoids from southern and eastern Poland is with respect to cyrtocrinids. Salamon (2008a, text-fig. 1A) documented highly diversified cyrtocrinids, consisting of fourteen taxa, in southern Poland. These sessile crinoids usually dwelled deeper (<100 m; the outer shelf) reef settings in the Mesozoic; recent cyrtocrinids also live at considerable depths (Hess, 1999c and literature therein).

In the Callovian clays of the Łuków drift the following crinoid taxa are documented: *Chariocrinus andreae*, *Balanocrinus* sp., *B. berchteni* Hess and Pugin, *B. pentagonalis*, *B. subteres*, *Isocrinus* sp., *I. nicoleti*, *I. pendulus*, *Pentacrinites* cf. *dargniesi*, Paracomatulidae gen. et sp. indet., and *Palaecomaster* sp. (Makowski, 1952; Salamon, 2008b). Only five of these taxa (or similar taxa) also are present in the Żebrak IG 1 borehole, in association with a few cyrtocrinid ossicles, also unknown from Łuków.

Crinoid assemblages from the Callovian of Lithuania are similar to those from Łuków (Salamon, 2008c). The sole exceptions are *Balanocrinus pendulus* and *Pentacrinites dargniesi*, which are known from Łuków, but are not recorded in Lithuania. On the other hand, Klikushin (1992) synonymized *B. pendulus* and *Isocrinus desori* and stated that the ossicles of this species are present in the lower Oxfordian of Papilė. It seems probable that some ossicles assigned to *I. desori* should actually belong to *I. nicoleti* (see discussion above). However, Jurassic crinoids from Lithuania may be more diversified, because Grewingk (1861), Eichwald (1868), Krenkel (1915) and Klikushin (1992) mentioned three other isocrinid taxa that were not recorded by Salamon (2008b).

B. pentagonalis from Lithuania was not observed in the Żebrak IG 1 borehole. On the other hand, ossicles of the pseudo-planktonic crinoid *Pentacrinites dargniesi* were observed in all Polish localities east of the Vistula River.

Interestingly, in European Russia, near Moscow and Riazan, a very similar crinoid assemblage, dominated by the isocrinids: *Isocrinus amblyscalaris* and *I. oxyscalaris* = = I. *pedulus* (see Salamon, 2008b), *Balanocrinus pentagonalis* and *Isocrinus*? *cingulatus*, was recorded (Klikushin, 1992 and Russian literature therein). The latter species is the only one known from Eastern Europe (also from southern Poland). Finally, it is noteworthy that so far no Callovian comatulids or cyrtocrinids have been described from the Russian localities mentioned. The only cyrtocrinid crinoid ever known was found in the Oxfordian near Moscow (Arendt, 1974).

Callovian crinoid assemblages from southern Poland, from areas located farther east (Łuków in Poland, Lithuania and Russia) and from eastern Poland (the Żebrak IG 1 borehole) differ to some extent with respect to their taxonomic composition (compare Tab. 1). This can be related to the specific bathymetric and facies preferences of particular crinoid taxa.

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