VOLUMINA JURASSICA, 2016, XIV: 133–144
DOI: 10.5604/17313708 .1222642

The Tithonian Chitinoidellidae and other microfossils from Owadów–Brzezinki quarry (central Poland)

Andrzej PSZCZÓŁKOWSKI[1]

Key words: Tithonian, microfossils, Central Poland.

Abstract. Tithonian (= "Middle Volgian") carbonate rocks are exposed in Owadów–Brzezinki quarry 19 km southeast of Tomaszów Mazowiecki, central Poland. In the upper part of the Sławno Limestone Member, chitinoidellids have been identified in thin sections from three samples, only. Therefore, the documented part of the Chitinoidella Zone in Owadów–Brzezinki quarry is about 0.3 m thick. The identified chitinoidellid taxa suggest that this assemblage represents the Upper Tithonian Boneti Subzone. The Chitinoidella Zone occurs at the top of Unit I and correlates with the uppermost interval of the Zarajskensis Horizon (Matyja, Wierzbowski, 2016). Other microfossils identified in the Chitinoidella Zone consist of *Saccocoma* sp. and benthic foraminifera of the genus *Planularia*.
Calcareous dinoflagellate cysts (*Cadosina semiradiata semiradiata* Wanner and *C*. cf. *semiradiata semiradiata* Wanner) occur above the chitinoidellid assemblage, in the strata corresponding to the Gerassimovi Subzone of the Virgatus Zone (Matyja, Wierzbowski, 2016). Calcareous nannofossils are extremely rare in the thin sections studied; only one small specimen was seen, identified as *Rhombolithion minutum* (Rood *et al*., 1971) Young *et* Bown 2014. In contrast, microbial filaments are frequently observed in the studied thin sections. Their shape and pattern are reminiscent of some recent Cyanobacteria of the order Nostocales, however the Tithonian microbial filaments are much thinner.

INTRODUCTION

Tithonian (= "Middle Volgian") carbonate sediments are exposed in Owadów–Brzezinki quarry 19 km southeast of Tomaszów Mazowiecki, central Poland (Kin, Błażejowski, 2012; Kin *et al*., 2013; Błażejowski *et al*., 2014; Fig. 1). The section, about 32 m thick, exposed in this quarry (Fig. 2) belongs to the Pałuki Formation (topmost part) and Kcynia Formation (Matyja, Wierzbowski, 2016). The chalky limestones of the lower part of the Kcynia Formation (11.3 m) are distinguished as the Sławno Limestone Member (Matyja, Wierzbowski, 2016). The bulk of these limestones belongs to the Scythicus Zone, Zarajskensis Subzone and Horizon (Matyja, Wierzbowski, 2016). The identified chitinoidellid taxa suggest that this assemblage may represent the Boneti Subzone. Other microfossils identified in the Chitinoidella Zone belong to *Saccocoma* sp. (ossicles) and benthic foraminifera.

MATERIAL FOR STUDY

Dr. Błażej Błażejowski collected the samples used for the present study (Fig. 2). I have examined under the light microscope over 200 thin sections made from 117 samples but of these only 18 samples contained microfossils identified and reported herein (Fig. 2). Many thin sections contain ostracods only, or are barren. The study and microphoto-

[1] Institute of Geological Sciences, Research Centre in Warszawa, Polish Academy of Sciences, Twarda Str. 51/55, 00-818 Warszawa, Poland; author's present address: Mozarta Str. 6/1103, 02-736 Warszawa; e-mail: pszczolkowski@yahoo.com.

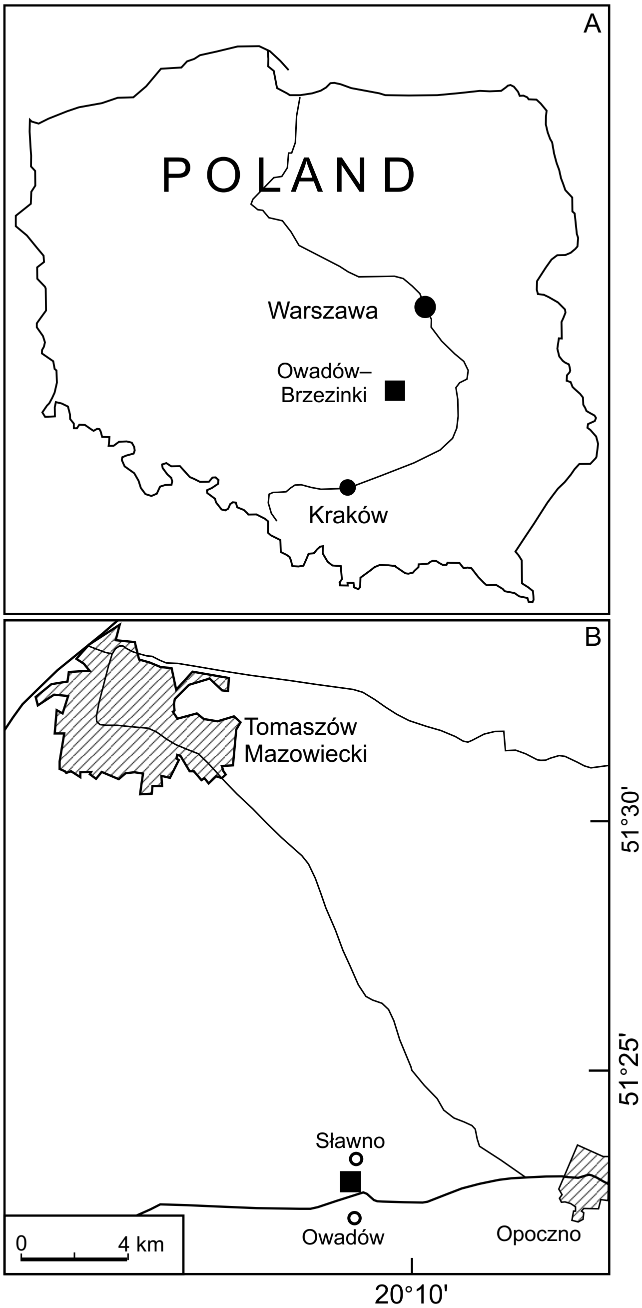

Fig. 1. A. Location of Owadów–Brzezinki quarry in Poland (after Kin *et al.*, 2012, fig. 1, modified). B. Location map of Owadów–Brzezinki quarry south of Sławno (partly after Salamon *et al.*, 2006, fig. 1B)

graphs of the microfossils from thin sections were made under a NIKON Polarizing Microscope (ECLIPSE LV100POL) in the Institute of Geological Sciences (Research Centre in Warsaw) of the Polish Academy of Sciences.

RESULTS

Only a few benthic foraminifera were found in the uppermost part of the Pałuki Formation (Fig. 2). The following taxa occur in sample SHW-99: *Mironovella* cf. *granulosa* (Bielecka et Pożaryski), *Lenticulina muensteri* (Roemer) and *Lenticulina* cf. *biexcavata* (Mjatliuk) (Fig. 5A–C). Chitinoidellids have been identified in the thin sections corresponding to three samples (SHW-69, B-43 and no. 4) collected from the upper part of the Sławno Limestone Member (Kcynia Formation). Therefore, the documented part of the Chitinoidella Zone in Owadów–Brzezinki quarry is about 0.3 m thick, only (Fig. 2). This biozone occurs at the top of the Unit I (massive chalky limestones of Błażejowski *et al.*, 2014), and correlates with the upper part of the Zarajskensis Subzone (Matyja *et al.*, 2016) and Horizon documented in the lower part of the section (Matyja, Wierzbowski, 2016). The chitinoidellid taxa found comprise: *Borziella* cf. *slovenica* (Borza, 1969) (Fig. 3B, C), *Chitinoidella* cf. *elongata* Pop, 1997 (Fig. 4A), *Chitinoidella* aff. *boneti* Doben, 1963 (Fig. 4B), *Daciella* cf. *banatica* Pop, 1998 (Fig. 3D), *Daciella* sp. (Fig. 3A) and *Dobeniella* sp. (Fig. 3E, F). A mould of a chitinoidellid similar to *Chitinoidella boneti* Doben, 1963 (Fig. 4C) was found in thin section no. 4. The identified chitinoidellid taxa suggest that this assemblage represents the Boneti Subzone. Other microfossils identified in the Chitinoidella Zone belong to *Saccocoma* sp. (scarce ossicles) and benthic foraminifera: *Planularia* cf. *poljenovae* (Kasanzev) and *P*. cf. *dofleini* Kusnetzova. Sporadic ossicles of *Saccocoma* sp. occur in the Sławno Limestone Member (Fig. 4D, E).

In the studied samples calcareous dinoflagellate cysts (*Cadosina semiradiata semiradiata* Wanner and *C*. cf. *semiradiata semiradiata* Wanner) occur above the chitinoidellid assemblage (Fig. 2), in the strata corresponding to the Gerassimovi Subzone of the Virgatus Zone (Matyja *et al.*, 2016; Matyja, Wierzbowski,2016). This upper part of the section correlates with the Albani Zone of the mid Tithonian in England and Northern France (Matyja *et al.*, 2016; Matyja, Wierzbowski, 2016). A specimen of *Pirumella* aff. *thayeri* (Bolli, 1974) Lentin et Williams (1993) was recorded at the base of the Sławno Limestone Member, well below the chitinoidellid assemblage (Fig. 2). In the Brodno section (Pieniny Klippen Belt, Slovakia), *C. tenuis* (included in the taxon *Pirumella thayeri* by Ivanova, Keupp, 1999) was recorded in the Dobeni and Boneti subzones of the Chitinoidella Zone, up to the Remanei Subzone of the Crassicollaria Zone (Michalík *et al.*, 2009, fig. 8).

Rogov (2014, fig. 1) correlated the Zarajskensis Subzone of the Scythicus Zone and the Gerassimovi Subzone of the

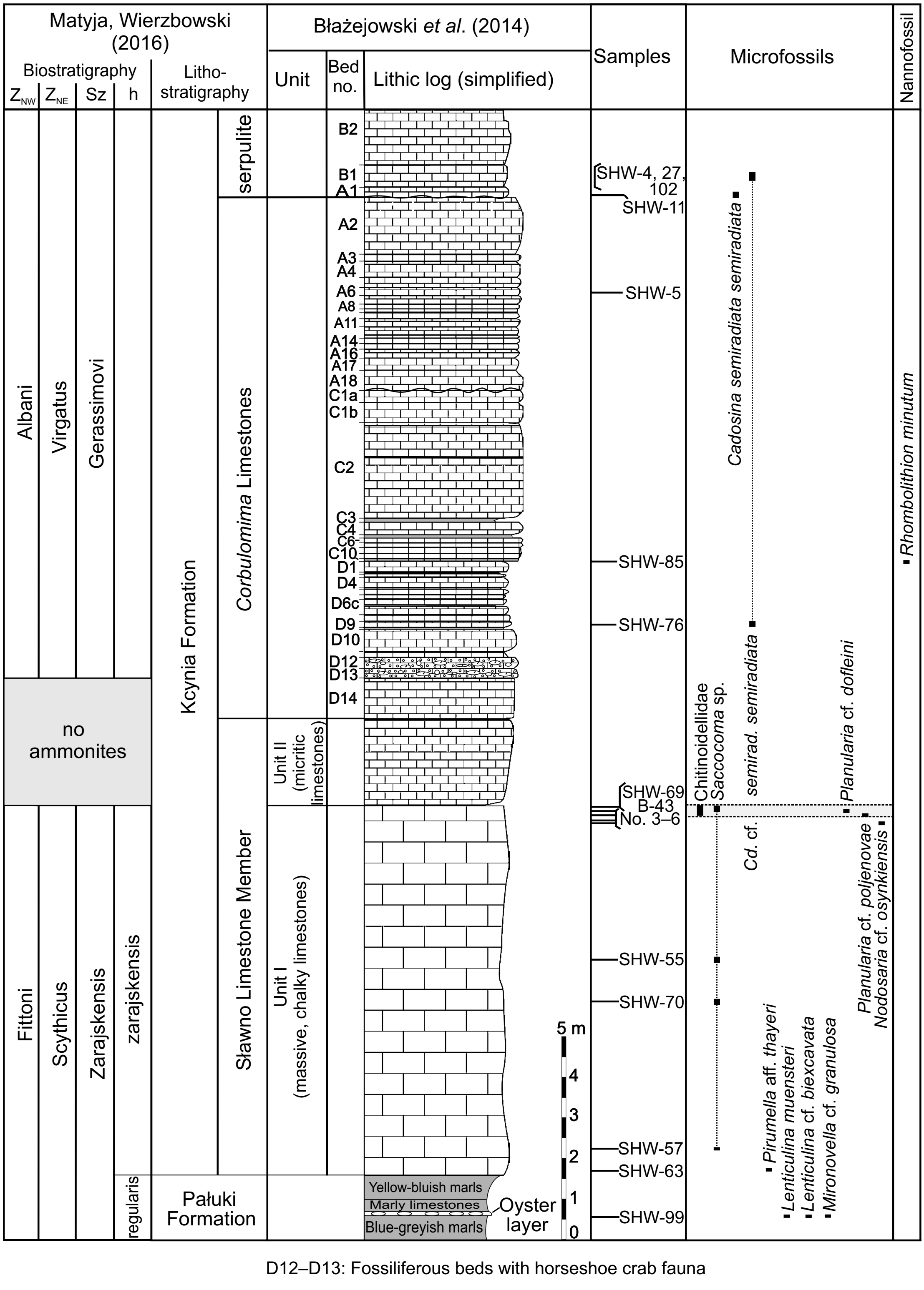

Fig. 2. Stratigraphical section exposed in Owadów–Brzezinki quarry. Ammonite biostratigraphy after Matyja, Wierzbowski (2016)

Z_{NW} – zones of the NW part of the Subboreal Province, Z_{NE} – zones of the NE part of the Subboreal Province, Sz – Subzones, h – horizons; samples location after B. Błażejowski (written information)

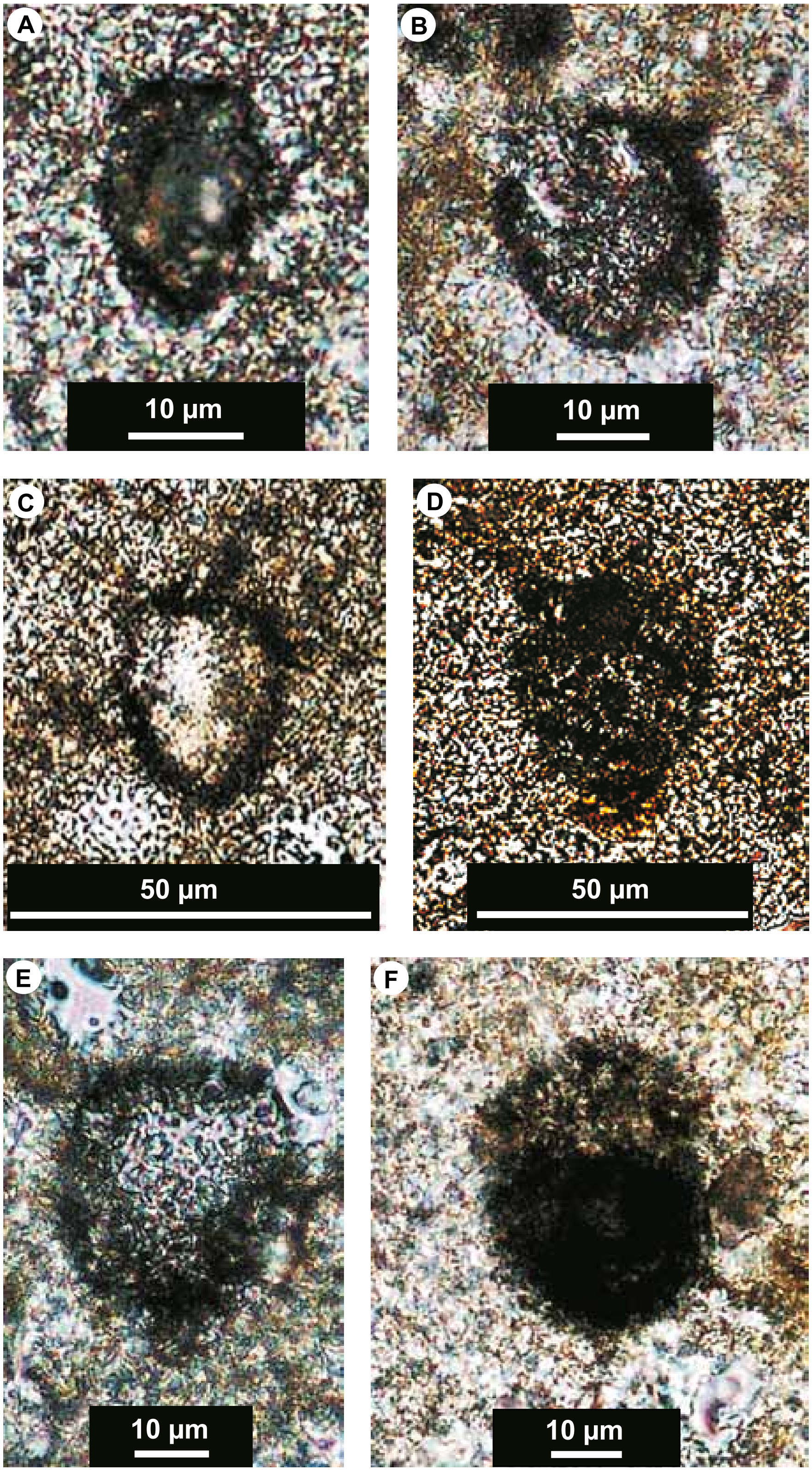

Fig. 3. Chitinoidellids identified in the sample/thin section SHW-69 (for location see Fig. 2)

A. *Daciella* sp. **B., C.** *Borziella* cf. *slovenica* (Borza, 1969). **D.** *Daciella* cf. *banatica* Pop, 1998. **E., F**. *Dobeniella* sp.

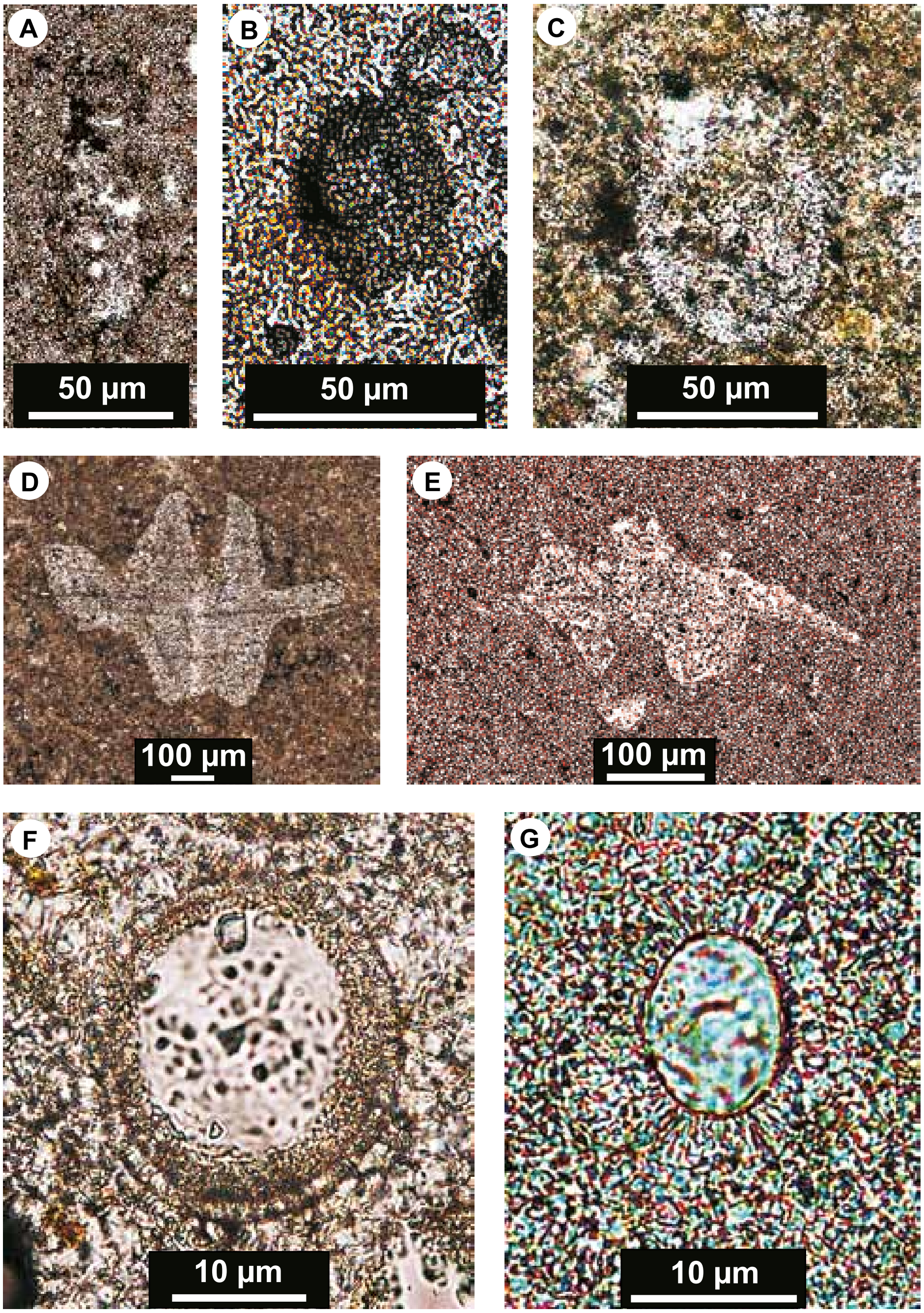

Fig. 4. Chitinoidellids, *Saccocoma*, *Cadosina* and *Pirumella*

A. *Chitinoidella* cf. *elongata* Pop, 1997, sample SHW-69, thin section B-43. **B.** *Chitinoidella* aff. *boneti* Doben, sample SHW-69, thin section B-43. **C.** Mould similar to *Chitinoidella boneti* Doben, 1963 (thin section no. 4). **D.** Ossicle of *Saccocoma* sp., sample SHW-70. **E.** Ossicle of *Saccocoma* sp., sample/thin section SHW-57. **F.** *Cadosina semiradiata semiradiata* Wanner, 1940, sample/thin section SHW-11. **G.** *Pirumella* aff. *thayeri* (Bolli, 1974) Lentin et Williams, 1993, sample SHW-63

Virgatus Zone of the Russian Platform with the upper part of the Lower Tithonian Ponti Zone (in Spain). If this correlation is correct, the chitinoidellid assemblage from Owadów–Brzezinki quarry should correspond to the upper part of the Ponti Zone in Spain. However, in the Puerto Escaño section (Spain), Pruner *et al*. (2010) have found the Dobeni/Boneti subzonal boundary in the Upper Tithonian Simplisphinctes Zone. Lakova, Petrova (2013) correlate the Dobeni/Boneti

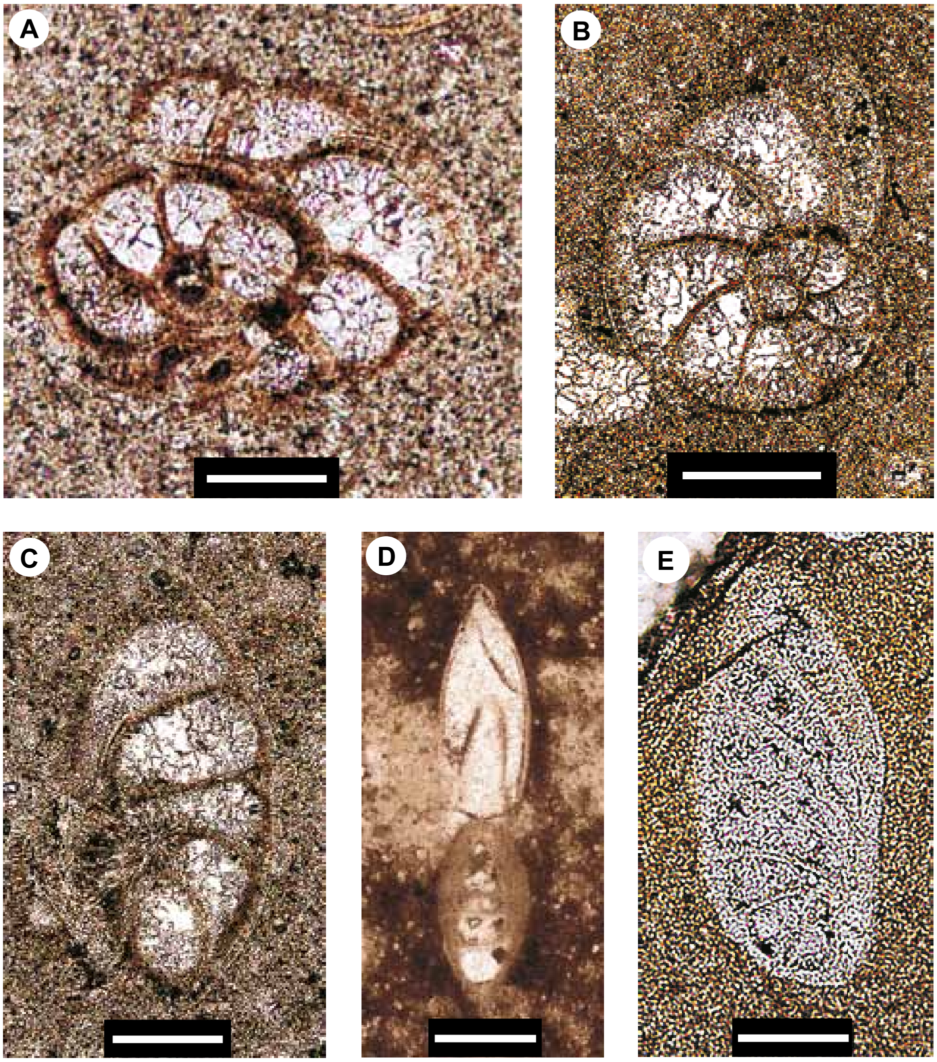

Fig. 5. Benthic foraminifera from the Pałuki Formation (A–C) and the Sławno Limestone Member (D–E)

A. *Mironovella* cf. *granulosa* (Bielecka et Pożaryski, 1954), sample/thin section SHW-99. **B.** *Lenticulina muensteri* (Roemer), sample/thin section SHW-99. **C.** *Lenticulina* cf. *biexcavata* (Mjatliuk, 1939), sample/thin section SHW-99. **D.** *Planularia* cf. *dofleini* (Kasanzev, 1936), additional thin section no. 3. **E.** *Planularia* cf. *poljenovae* Kusnetzova, 1960 (additional thin section no. 4). Scale bar – 100 µm

subzonal boundary with the base of the Upper Tithonian. Therefore, the uppermost part of the Zarajskensis Subzone and the Gerassimovi Subzone in Owadów–Brzezinki quarry may belong to the Upper Tithonian.

CONCLUSIONS

In Owadów–Brzezinki quarry (Central Poland), the following benthic foraminifera occur in the uppermost part of the Pałuki Formation: *Lenticulina muensteri*, *L.* cf. *biexcavata* and *Mironovella* cf. *granulosa.*

Chitinoidellidae have been identified in the upper part of the Sławno Limestone Member (Kcynia Formation). The taxa found include: *Borziella* cf. *slovenica* (Borza), *Chitinoidella* cf. *elongata* Pop, *Chitinoidella* aff. *boneti* Doben, *Daciella* cf. *banatica* Pop, *Daciella* sp. and *Dobeniella* sp. A mould similar to *Chitinoidella boneti* Doben was also found.

The documented part of the Chitinoidella Zone only is about 0.3 m thick. The chitinoidellid taxa indicate the lower part of the Boneti Subzone. Other microfossils identified in the Chitinoidella Zone belong to *Saccocoma* sp. (ossicles) and benthic foraminifera: *Planularia* cf. *poljenovae* (Kasanzev) and *P*. cf. *dofleini* Kusnetzova.

The Boneti Subzone of the Chitinoidella Zone found in the quarry correlates with the upper part of the Zarajskensis Subzone and Horizon recognized in the lower part of the section (Matyja, Wierzbowski, 2016). Therefore, the upper part of the Zarajskensis Subzone of the Scythicus Zone and the Gerassimovi Subzone of the Virgatus Zone may belong to the Upper Tithonian.

The calcareous dinoflagellate cysts *Cadosina semiradiata semiradiata* Wanner and *C.* cf. *semiradiata semiradiata* Wanner occur above the chitinoidellid assemblage, in the strata corresponding to the Gerassimovi Subzone (Matyja *et al*., 2016; Matyja, Wierzbowski, 2016). One specimen of *Pirumella* aff. *thayeri* (Bolli, 1974) Lentin et Williams (1993) (or *Colomisphaera* aff. *tenuis* [Nagy, 1966]) was recorded at the base of the Sławno Limestone Member.

SYSTEMATIC NOTES

Chitinoidellids

Borziella cf. *slovenica* (Borza, 1969)
Fig. 3B, C

Description: Two small specimens with an oval (B) to almost subtriangular lorica (C). The specimens are 27 µm and 32 µm in length, 24.8 and 22.5 µm in width, respectively. The collar is rather short, funnel-like.

Remarks: The specimen shown in Figure 3B is similar to the holotype of *B. slovenica* (Borza, 1969, pl. LXVI, fig. 9). The other specimen (Fig. 3C) is similar to *B. slovenica* figured by Borza (1969, pl. LXVI, fig. 12). According to Reháková (2002), *B. slovenica* (Borza, 1969) occurs in the Dobeni Subzone of the Tithonian Chitinoidella Zone.

Chitinoidella cf. *elongata* Pop, 1997
Fig. 4A

Description: A poorly preserved specimen with an outwardly deflected collar; the lorica is about 84 µm long and 41 µm wide. The caudal appendage is not visible.

Remarks: The shape and dimensions of the specimen are typical of *Ch. elongata* Pop (cf. Pop, 1997 and Reháková, 2002), but the details of its structure are obliterated.

Chitinoidella aff. *boneti* Doben, 1963
Fig. 4B

Description: Bell-shaped lorica, 39 µm long and 35.7 µm wide, with a preoral constriction. The length/width ratio is about 1.1. The aboral end of the lorica is sharp, with a short caudal appendage.

Remarks: The figured specimen is similar to *Chitinoidella boneti* Doben, but is smaller in comparison with the dimensions reported for this species (Borza, 1969; Reháková, 2002).

Daciella cf. *banatica* Pop, 1998
Fig. 3D

Description: The figured specimen (46.1 µm long and 37.3 µm wide) has a conical lorica (38.8 µm in longitud) sharply terminated at the aboral pole, but the caudal appendage is not visible. The outwardly deflected collar seems to be as wide as the maximum width of the lorica.

Remarks. The rather poor preservation of the specimen does not allow its full identification to species level. It is similar to the holotype (Pop, 1998, fig. 1.2), excepting the caudal appendage, which is not observed in this section.

Daciella sp.
Fig. 3A

Description: A small specimen, 21.5 µm long and 14.3 µm wide, with a conical and slightly elongate lorica. The aboral pole is pointed but the caudal appendage is (almost) invisible. The oral end of the lorica shows a characteristic constriction 1.3 µm wide. The rather large oral opening bears a short collar preceded by a distinct swelling.

Remarks: The specimen is similar to *Daciella banatica* n. sp. (Pop, 1998, fig. 2: 8–9) and also to *Chitinoidella* sp. illustrated by Borza (1969, pl. LXIX, fig. 6) and included by Pop (1998) in the synonymy of *D. banatica* n. sp. However, the specimen figured herein is smaller than the holotype and paratype of *D. banatica* Pop, and the caudal appendage is hardly visible in Figure 3A. According to Pop (1998), the species of *Daciella* occur in the Chitinoidella and Praetintinnopsella zones (Tithonian).

Dobeniella sp.
Fig. 3E, F

Description: The specimen with a bell-shaped lorica and short aboral horn (Fig. 3E) is 36 µm long and 34 µm wide. The collar is hardly visible, but is similar to that of *D. colomi* (Borza, 1966). The lorica is filled with fossilized microbial filaments, also overgrowing the aboral horn. The specimen shown in Fig. 3F is 40.4 µm long and 28 µm wide, with an ovoid lorica about 24 µm long. A constriction separates the lorica from the collar, which is poorly visible because of microbial filaments filling the specimen. The caudal appendage is sharply pointed, about 7 µm long.

Remark: Both chitinoidellids are poorly preserved, but their shape is similar to *Dobeniella* Pop, 1997. The specimen shown in Fig. 3F cannot be identified to species rank because the structure of the collar is not fully discernible.

Saccocomid ossicles

Saccocoma sp.
Fig. 4D, E

Remarks: The figured fragments of *Saccocoma* sp. are small skeletal sections observed in two different thin sections (from sample SHW-70 and SHW-57). The first one (Fig. 4D) shows a section similar to the second primibrachials of *S.* aff. *vernioryi* Manni & Nicosia (Brodacki, 2006, fig. $4E_4$). The saccocomid fragment shown in Fig. 4E is similar to the skeletal element BI (Benzaggagh *et al*., 2015, fig. 4) described therein as "irregular heads with one or two foots and two lateral appendices (irg. Hd)". In the stratigraphical scheme for the western Tethyan realm (Benzaggagh *et al*., 2015, fig. 17) the skeletal sections, labelled BE in their figure 17, are abundant in saccocomid biozone 4, which corresponds to the ammonite zones Darwini–Semiforme (Lower Tithonian).

Calcareous dinoflagellates

Cadosina cf. *semiradiata semiradiata* Wanner, 1940
Fig. 4F

Remarks: The figured specimen found in the sample SHW-4 (54 µm in diameter) is similar to *Cadosina semiradiata semiradiata* Wanner, 1940 (*cf.* Ivanova, Keupp, 1999, pl. I, figs 6–7; Reháková, 2000a, pl. II, fig. 6). The wall of the test (about 11 µm) consists of a dark inner layer (7 µm) and a light grey outer one (4 µm). The calcareous dinoflagellate *Cadosina* cf. *semiradiata semiradiata* Wanner was also found in other samples (SHW: 11, 27, 76 and 102). Ivanova, Keupp (1999) included *Cadosina semiradiata semiradiata* in the species *Pirumella multistrata* (Pflaumann et Krasheninnikov, 1978) Lentin et Williams, 1993 from the subfamily Obliquipithonelloideae Keupp, 1987. Reháková (2000a, b) placed the Semiradiata Zone in the Middle Tithonian.

Pirumella aff. *thayeri* (Bolli, 1974) Lentin et Williams 1993
Fig. 4G

Remarks: The small specimen identified as *Pirumella* aff. *thayeri* is ovate in shape. The maximal diameter of the test is 18 µm only, whereas the wall thickness attains 3.7 µm. According to Bolli (1980), the tests of the genus *Pirumella* are circular to ovate in axial section. Although very small, the figured specimen is partly similar to *Colomisphaera tenuis* (Nagy, 1966) reported by Ivanova, Keupp (1999) from the base of the Chitinoidella Zone (Middle Tithonian) to the Lower Berriasian C. alpina Subzone. Řehánek (1992, fig. 2) placed the Tenuis Zone at the Lower/Upper Tithonian boundary. According to Reháková (2000a), *C. tenuis* ranges from the Middle Tithonian to the Upper Berriasian.

Benthic foraminifera

Mironovella cf. *granulosa* (Bielecka et Pożaryski, 1954)
Fig. 5A

Remarks: The figured specimen, found in the sample/thin section SHW-99, is similar to the holotype illustrated by Bielecka, Pożaryski (1954, pl. XII, fig. 61b) as *Epistomina stellicostata* var. *granulosa. Mironovella granulosa* was reported to occur from the Late Oxfordian to Early Tithonian in the northern epicontinental areas of the Tethys (Görög, Wernli, 2013).

Lenticulina muensteri (Roemer, 1839)
Fig. 5B

1839. *Robulina Münsteri* Roemer; Roemer, p. 48, pI. 20, fig. 29 (*fide* Cat. of Foram. Ellis & Messina, 1940) – *vide* Jendryka-Fuglewicz (1975) (see Jendryka-Fuglewicz, 1975 for synonymy up to 1975).

1975. *Lenticulina muensteri* (Roemer); Jendryka-Fuglewicz, p. 149, pl. VIII–X, pl. XI, figs 1–6, pl. XIX, pl. XX, figs 1, 2.

1983. *Lenticulina muensteri* (Roemer, 1839); Peryt, p. 440, pl. 24: 7, 8.

1986. *Lenticulina muensteri* (Roemer); Bartenstein & Bolli, pl. 4, figs 25, 26.

1995. *Lenticulina muensteri* (Roemer); Holbourn & Kaminski, p. 214, pl. 6, figs 11a, b.

Description: The specimen has an involute test with 8 chambers in the last whorl; the sutures are markedly curved backward. The maximum diameter of the test attains 282 µm.

Remarks: The figured section, found in the sample/thin section SHW-99, is similar to the morphotype *wiśniowskii* of *L. muensteri* occurring in the Middle and Upper Jurassic (Jendryka-Fuglewicz, 1975).

Lenticulina cf. *biexcavata* (Mjatliuk, 1939)
Fig. 5C

Remarks: The specimen is an equatorial section 394 µm in length, partly overgrown with microbial filaments; therefore, only 5 chambers are visible in the outer whorl. The sutures are usually arcuate and depressed. The specimen was found in the sample/thin section SHW-99 and is similar to tests illustrated by Jendryka-Fuglewicz (1975, pl. III, figs 5–8) being, however, more slender in the equatorial section. According to Jendryka-Fuglewicz (1975), *L. biexcavata* is known from the Middle Jurassic of Poland, Lower Kimmeridgian of France and "Lower Volgian" in Russia.

Planularia cf. *dofleini* (Kasanzev, 1936)
Fig. 5D

Remarks: The figured peripheral section is broadly similar to the test of *Planularia dofleini* (Kasanzev) illustrated by Bielecka (1975, pl. IX, fig. 1b). However, the specimen shown in Fig. 5D is much smaller (410 μm in length). In Poland, *P. dofleini* (Kasanzev) was reported from the Zaraiskites scythicus and Z. zaraiskensis zones ("Middle Portlandian" – Bielecka, 1975, table III).

Planularia cf. *poljenovae* Kusnetzova, 1960
Fig. 5E

Remarks: The specimen identified as *Planularia* cf. *poljenovae* Kusnetzova, 376 μm in length, is broadly similar to *P. poljenovae* illustrated by Bielecka (1975, pl. IX, figs 4–7), although its upper part seems to be less elongated than the tests shown in that publication. According to Bielecka (1975), *P. poljenovae* is known from the lower and middle "Portlandian" in Poland and the lower and middle "Volgian" on the Russian Platform.

NANNOFOSSIL AND MICROBIAL FILAMENTS

Calcareous nannofossils are extremely rare in the studied thin sections; only one small specimen was identified (Fig. 6A, n) as *Rhombolithion minutum* (Rood *et al*., 1971) Young et Bown 2014 (*cf.* Young *et al*., 2015). Originally this taxon was described as *Diadorhombus minutus* Rood *et al.*, 1971 (see also Rood, Barnard, 1972) from the Oxfordian, however its stratigraphical range seems to be wider because De Kaenel, Bergen (1996) reported *Diadorhombus scutulatus* (Medd, 1971), Medd, 1979 from the Lower Tithonian at Hole 901A (Atlantic Ocean). According to Young *et al.* (2015), the taxa *R. minutum* and *R. scutulatus* (Medd, 1971) Young et Bown 2014 "are evidently synonyms it is not clear yet which has priority".

The above described nannofossil is surrounded by microbial filaments 0.15–0.80 μm wide and up to 4 μm long (Fig. 6A, f). Although thinner, the filaments (usually branched) are similar to some recent Cyanobacteria from the order Nostocales (Komárek *et al*., 2014). Microbial filaments are frequently observed in the studied thin sections. The filaments 0.2–0.6 μm wide (Fig. 6B) probably infilling the space occupied by a microfossil, which no longer exists. Their shape and pattern are reminiscent of some recent Cyanobacteria from the family Hapalosiphonaceae, order Nostocales (Komárek *et al*., 2014). The filaments reveal true branching; some terminal cells are similar to heterocysts (Fig. 6B, tc). However, the figured fossil filaments are much thinner than the recent Cyanobacteria. For example, the genus *Mastigocoleus* Lagerheim has trichomes 4–6 μm wide (Wuitner, 1921, fig. 9; Carreiro-Silva *et al*., 2012, fig. 2f). Some other genera of the family Hapalosiphonaceae, such as *Fischerella* Gomont, have trichomes about 3–6 μm wide (*cf.* Rippka *et al*., 1979, figs 73–78). Therefore, the figured microbial filaments (Fig. 6B) cannot be considered as the Tithonian equivalents of the above mentioned recent cyanobacterial taxa.

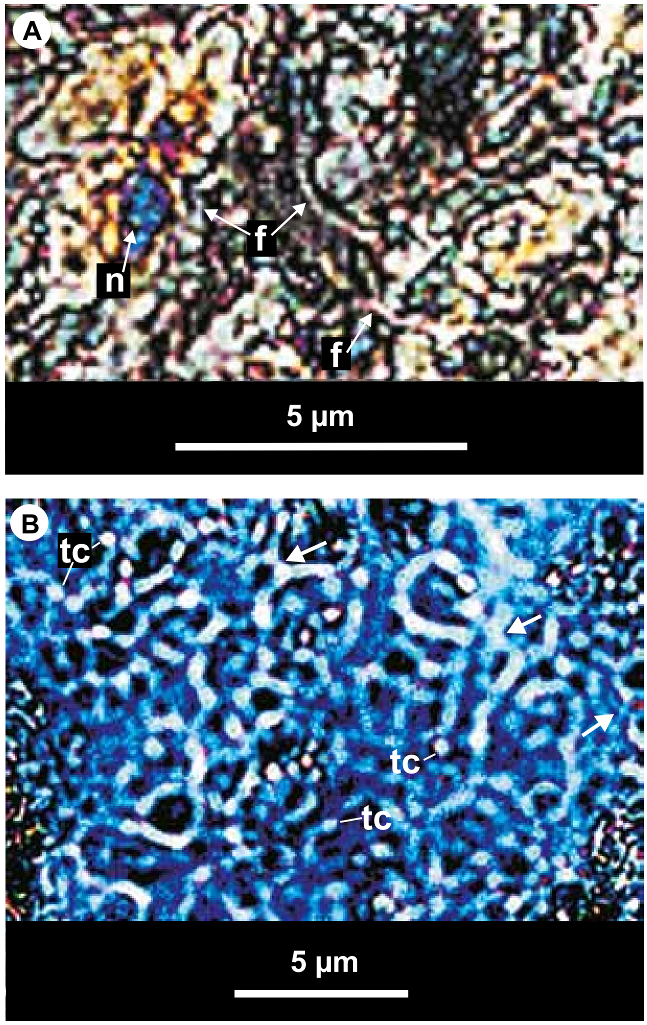

Fig. 6. A. Nannofossil (n) identified as ***Rhombolithion minutum*** **(Rood *et al*., 1971) Young et Bown 2014 and microbial filaments (f); *Corbulomima* Limestone Member, sample/thin section SHW-85; B. Microbial filaments (tc – terminal cells slightly similar to cyanobacterial heterocysts, but much smaller – 0.4–0.6 μm wide; arrows indicate branching of filaments); sample/thin section SHW-5, *Corbulomima* Limestone Member, bed no. A6**

Acknowledgements. The study was supported by the Polish National Science Centre (grant no. 2012/07/B/ST10/04175. I am grateful to B. Błażejowski for location of samples shown in Fig. 2, and also for making the thin sections accessible for the present study. I am also grateful to B.A. Matyja and A. Wierzbowski who were helpful in allowing access to their unpublished work. Reviews by D. Reháková and S. Petrova improved the manuscript and are greatly appreciated.

REFERENCES

BARTENSTEIN H., BOLLI H.M., 1986 — The Foraminifera in the Lower Cretaceous of Trinidad, W.I., Part 5: Maridale Formation, upper part; Hedbergella rohri zone. *Eclogae Geologicae Helvetiae*, **79**, 3: 945–999.

BENZAGGAGH M., HOMBERG C., SCHNYDER J., BEN ABDESSELAM-MAHDAOUIDA S., 2015 — Description et biozonation des sections de crinoïdes saccocomidés du Jurassique supérieur (Oxfordien-Tithonien) du domaine téthysien occidental. *Annales de Paléontologie*, **101**, 2: 95–117.

BIELECKA W., 1975 — Foraminifera and brackish Ostracoda from the Portlandian of Polish Lowlands. *Acta Palaeontologica Polonica*, **20**, 3: 295–393.

BIELECKA W., POŻARYSKI W., 1954 — Stratygrafia mikropaleontologiczna górnego malmu w Polsce środkowej (Micropaleontological stratigraphy of the upper Malm in central Poland). *Prace Instytutu Geologicznego*, **12**: 1–77.

BŁAŻEJOWSKI B., MATYJA B.A., WIERZBOWSKI A., WIERZBOWSKI H., 2014 — A new exceptionally preserved Late Jurassic ecosystem (Owadów–Brzezinki, Central Poland) and its geological background. *In*: Jurajskie utwory synkliny tomaszowskiej (eds A. Feldman-Olszewska, A. Wierzbowski), Jurassica XI: 21–26. Państwowy Instytut Geologiczny – PIB, Warszawa.

BOLLI H.M., 1974 — Jurassic and Cretaceous Calcisphaerulidae from DSDP Leg 27, Eastern Indian Ocean. *In:* Initial Reports of the Deep Sea Drilling Project (eds J.R. Veevers *et al*.), **27**: 843–907. Washington (U.S. Government Printing Office).

BOLLI H.M., 1980 — Calcisphaerulidae and Calpionellidae from the Upper Jurassic and Lower Cretaceous of Deep Sea Drilling Project Hole 416A, Moroccan basin. *In*: Initial Reports of the Deep Sea Drilling Project, **50**: 525–543. Washington (U.S. Government Printing Office).

BORZA K., 1966 — Neue Arten der Gattung *Chitinoidella* Doben, 1962 in den Westkarpaten. *Geologický Sbornik Slovenskej Akademie Vied*, **17**, 2: 259–265.

BORZA K., 1969 — Die Mikrofazies und Mikrofossilien des Oberjuras und der Unterkreide der Klippenzone der Westkarpaten. Vydavatelstvo Slovenskej Akadémie Vied, Bratislava, 301 pp.

BRODACKI M., 2006 — Functional anatomy and mode of life of the latest Jurassic crinoid *Saccocoma*. *Acta Palaeontologica Polonica,* **51**, 2: 261–270.

CARREIRO-SILVA M., KIENE W.E., GOLUBIC S., McCLANAHAN T.R., 2012 — Phosphorus and nitrogen effects on microbial euendolithic communities and their bioerosion rates. *Marine Pollution Bulletin*, **64**: 602–613.

De KAENEL E., BERGEN J.A., 1996 — 2. Mesozoic calcareous nannofossil biostratigraphy from Sites 897, 899 and 901, Iberia Abyssal Plain: new biostratigraphic evidence. *In*: Proceedings of the Ocean Drilling Program, Scientific Results (eds R.B. Whitmarsh *et al.*), **149**: 27–48.

DOBEN K., 1963 — Über Calpionelliden an der Jura/Kreide-Grenze. *Mitteilungen der Bayerischen Staatssammlung für Paläontologie und historische Geologie*, **3**: 35–50.

ELLIS B.F., MESSINA A. (eds), 1940 — Catalogue of Foraminifera. Micropaleontology Press, New York, American Museum of Natural History, Supplements, post-1940.

GÖRÖG A., WERNLI R., 2013 — The Kimmeridgian marker foraminifer *Parinvolutina aquitanica* Pelissié & Peybernès, 1982 is a junior synonym of *Mironovella granulosa* (Bielecka & Pozaryski, 1954), Epistominidae. *Archives des Sciences*, **66**: 1–10.

HOLBOURN A.E.L., KAMINSKI M.A., 1995 — Valanginian to Barremian benthic foraminifera from ODP Site 766 (Leg 123, Indian Ocean). *Micropaleontology*, **41**, 3: 197–250.

IVANOVA D., KEUPP H., 1999 — Calcareous dinoflagellate cysts from the Late Jurassic and Early Cretaceous of the Western Forebalkan, Bulgaria. *Berliner geowissenschaftliche Abhandlungen*, **30**: 3–31.

JENDRYKA-FUGLEWICZ B., 1975 — Evolution of the Jurassic and Cretaceous smooth-walled *Lenticulina* (Foraminiferida) of Poland. *Acta Palaeontologica Polonica*, **20**, 2: 99–197.

KASANZEV V.P., 1936 — Materialy k poznaniu foraminifer neokoma i jury Embaenskogo raiona. *Trudy NIGRI*, ser. A, **56**: 1–26.

KEUPP H., 1987 — Die kalkigen Dinoflagellaten-Zysten des Mittelalb bis Untercenoman von Escalles/Boulonnais (N-Frankreich). *Facies*, **16**: 37–88.

KIN A., BŁAŻEJOWSKI B., 2012 — Polskie Solnhofen (Polish Solnhofen). *Przegląd Geologiczny*, **60**: 375–379.

KIN A., BŁAŻEJOWSKI B., BINKOWSKI M., 2012 — The 'Polish Solnhofen': a longawaited alternative? *Geology Today*, **28**, 3: 91–94.

KIN A., GRUSZCZYŃSKI M., MARTILL D., MARSHALL J.D., BŁAŻEJOWSKI B., 2013 — Palaeoenvironment and taphonomy of a Late Jurassic (Late Tithonian) Lagerstätte from central Poland. *Lethaia*, **46**: 71–81.

KOMÁREK J., KAŠTOVSKÝ J., MAREŠ J., JOHANSEN J.R., 2014 — Taxonomic classification of cyanoprokaryotes (cyanobacterial genera) 2014, using a polyphasic approach. *Preslia*, **86**: 295–335.

KUSNETZOVA K.I., 1960 — Rod *Planularia* i ego novye vidy iz verkhnej Jury Russkoj platformy. *Paleontologicheskij Zurnal*, **2**: 17–34.

LAKOVA I., PETROVA S., 2013 — Towards a standard Tithonian to Valanginian calpionellid zonation of the Tethyan Realm. *Acta Geologica Polonica*, **63**, 2: 201– 221.

LENTIN J.K., WILLIAMS G.L., 1993 — Fossil dinoflagellates: Index to genera and species, 1993 Edition. *American Association of Stratigraphic Palynologists Contributions Series*, **28**: 1–856.

MATYJA B.A., WIERZBOWSKI A., 2016 — Ammonites and ammonite stratigraphy of the uppermost Jurassic (Tithonian) of the Owadów–Brzezinki quarry (central Poland). *Volumina Jurassica*, **14**: 65–122.

MATYJA B.A., PSZCZÓŁKOWSKI A., WIERZBOWSKI A., 2016 — A Tithonian *Chitinoidella* horizon and „Volgian" and „Portlandian" ammonites in the Owadów–Brzezinki section (central Poland) – a clue for Upper Jurassic interregional correlations. *In*: XIIth Jurassica Conference (eds J. Michalík, K. Fekete). Field trip guide and Abstracts Book: 65–67. 19–23 April, 2016, Smolenice, Slovakia. Earth Science Institute, Slovak Academy of Sciences, Bratislava 2016.

MEDD A.W., 1971 — Some Middle and Upper Jurassic Coccolithophoridae from England and France. Proc. IInd Planktonic Conference, Rome: 821–845.

MEDD A.W., 1979 — The Upper Jurassic coccoliths from the Haddenham and Gamlingay boreholes (Cambridgeshire, England). *Eclogae Geologicae Helvetiae*, **72**: 19–109.

MICHALÍK J., REHÁKOVÁ D., HALÁSOVÁ E., LINTNEROVÁ O., 2009 — The Brodno section – a potential regional stratotype of the Jurassic/Cretaceous boundary (Western Carpathians). *Geologica Carpathica*, **60**, 3: 313–232.

MJATLIUK E.V., 1939 — Foraminifery verkhnejurskich i nizhnemelovykh otlozhenij srednego Povolzja i Obscego Syrta. *Trudy VNIGRI, ser. A*, **120**: 2–68.

NAGY I., 1966 — A *Stomiosphaera* és a *Cadosina* nemzetség rétegtani szerepe a Mecseki felsöjurában (Sur le rôle stratigraphique des genres *Stomiosphaera* et *Cadosina* dans le Jurassique supérieur de la Montagne Mecsek*). Földtani Közlöny*, **96**, 1: 86–104.

PERYT D., 1983 — Mid-Cretaceous microbiostratigraphy and foraminifers of the NE Margins of the Świętokrzyskie (Holy Cross) Mts., Poland. *Acta Palaeontologica Polonica*, **28,** 3/4: 417–466.

PFLAUMANN U., KRASHENINNIKOV V.A., 1978 — Cretaceous calcisphaerulids from DSDP Leg 41, eastern North Atlantic. *In*: Initial Reports of the Deep Sea Drilling Project, **41**: 817–839. Washington (U.S. Government Printing Office).

POP G., 1997 — Révision systématique des chitinoidelles tithoniennes des Carpathes méridionales (Roumanie). *C. R. Acad. Sci. Paris*, **324**, série IIa: 931–938.

POP G., 1998 — Nouvelles chitinoïdelles tithoniennes des Carpathes méridionales (Roumanie). *C. R. Acad. Sci. Paris*, *serie II fascicule A – Sciences de la terre et des planètes/Earth & Planetary Sciences*), **326**: 817–822.

PRUNER P., HOUŠA V., OLÓRIZ F., KOŠŤÁK M., KRS M., MAN O., SCHNABL P., VENHODOVÁ D., TAVERA J.M., MAZUCH M., 2010 — High-resolution magnetostratigraphy and biostratigraphic zonation of the Jurassic/Cretaceous boundary strata in the Puerto Escaño section (southern Spain). *Cretaceous Research,* **31**: 192–206.

REHÁKOVÁ D., 2000a — Evolution and distribution of the Late Jurassic and Early Cretaceous calcareous dinoflagellates recorded in the Western Carpathian pelagic carbonate facies. *Mineralia Slovaca*, **32**: 79–88.

REHÁKOVÁ D., 2000b — Calcareous dinoflagellate and calpionellid bioevents versus sea-level fluctuations recorded in the west-Carpathian (Late Jurassic/Early Cretaceous) pelagic environments. *Geologica Carpathica*, **51**, 4: 229–243.

REHÁKOVÁ D., 2002 — *Chitinoidella* Trejo, 1975 in Middle Tithonian carbonate pelagic sequences of the West Carpathian Tethyan area. *Geologica Carpathica*, **53**, 6: 369–379.

ŘEHÁNEK J., 1992 — Valuable species of cadosinids and stomiospherids for determination of the Jurassic–Cretaceous boundary (vertical distribution, biozonation). *Scripta* (*Geology*), **22**: 117–122.

RIPPKA R., DERUELLES J., WATERBURY J.B., HERDMAN M.R., STANIER R.Y., 1979 — Generic assignments, strain histories and properties of pure cultures of *Cyanobacteria*. *Journal of General Microbiology*, **111**: 1–61.

ROGOV M.A., 2014 — Infrazonal subdivision of the Volgian Stage in its type area using ammonites and correlation of the Volgian and Tithonian stages. *In*: STRATI 2013 – First International Congress on Stratigraphy. At the Cutting Edge of Stratigraphy (eds R. Rocha *et al.*), 557–580. Springer Verlag.

ROOD A.P., BARNARD T., 1972 — On Jurassic Coccoliths: *Stephanolithion*, *Diadozygus* and related genera. *Eclogae Geologicae Helvetiae*, **65**: 327–342.

ROOD A.P., HAY W.W., BARNARD T., 1971 — Electron Microscope Studies of Oxford Clay Coccoliths. *Eclogae Geologicae Helvetiae*, **64**: 245–272.

SALAMON M.A., ZATOŃ M., KIN A., GAJERSKI A., 2006 — Tithonian (Upper Jurassic) crinoids from central Poland. *Paläontologie, Stratigraphie, Fazies* (14), Freiberger Forschungshefte, **C 511**: 29–38.

WANNER J., 1940 — Gesteinsbildende Foraminiferen aus Malm und Unterkreide des östlichen Ostindischen Archipels nebst Bemerkungen über *Orbulinaria* Rhumbler und andere verwandte Foraminiferen. *Paläontologische Zeitschrift*, **22**: 75–97.

WUITNER E., 1921 — Encyclopédie pratique du naturaliste. VII – les algues marines des côtes de France (Manche et Océan), Cyanophycées, p. 41–43 (Ed. P. Lechevalier), Paris VI.

YOUNG J.R., BOWN P.R., 2014 — Some emendments to calcareous nannoplankton taxonomy. *Journal of Nannoplankton Research*, **33,** 1: 39–46.

YOUNG J.R., BOWN P.R., LEES, J.A., 2015 — Nannotax3 – Mesozoic: http://ina.tmsoc.org/Nannotax3/index.php?dir=Mesozoic/Stephanolithiales/ Stephanolithiaceae/Rhombolithion/Rhombolithion minutum.