Foraminiferal bioevents in the Upper Campanian to lowest Maastrichtian of the Middle Vistula River section, Poland

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The Upper Campanian–Lower Maastrichtian interval of the Middle Vistula River valley section records the following benthic foraminiferal bioevents in ascending stratigraphical order: LO of Globorotalites michelinianus, FO and LO of Globorotalites emdyensis (= G. hiltermanni), FO of Bolivina incrassata, FO of Bolivinoides miliarum (= A. bettenstaedti), LO of Gavelinella monterelenis, FO of Osangularia navarroana, FO of Bolivina decurrens and FO of Neoflabellina reticulata. These events are recorded in very similar stratigraphic positions in the Lägerdorff-Kronsmoor and in the succession of eastern Germany and, to some extent, of eastern Europe. Accordingly they can serve as important markers for stratigraphic correlation across Europe. The FOs of the planktonic species, Rugoglobigerina milamensis, R. hexacamerata and R. pennyi, in the uppermost part of the “Inoceramus redbirdensis” Zone, are very close to the Campanian/Maastrichtian boundary as defined by inoceramid bivalves (Walaszczyk, 2004) and we propose these planktonic foraminiferal bioevents as a good proxy for this boundary in temperate regions.

Key words: Campanian/Maastrichtian boundary, foraminifera, bioevents, stratigraphic correlation, Middle Vistula River valley section.

INTRODUCTION

Foraminifera, especially planktonic forms, are one of the stratigraphically most important fossils in the Upper Cretaceous and are extensively used in interregional correlation due to their widespread distribution and high rate of evolution (e.g., Bolli, 1966; Robaszynski and Caron, 1995; Hardenbol et al., 1998). However, their usefulness is limited in many regions, mostly in high latitudes and in areas of shelf sedimentation (Bé, 1977; Premoli Silva and Sitter, 1999). The distribution of planktonic foraminifera in Cretaceous seas and oceans was, similar to today, strongly influenced by sea depth, temperature, food supply and latitude. The diversity of modern planktonic foraminifera decreases from the tropics towards high latitudes by the progressive loss of warm-water and morphologically complex species. As a result, high-latitude assemblages are dominated by the most tolerant cosmopolitan forms with simple morphologies (Bé, 1977; Hemleben et al., 1989; Premoli Silva and Sitter, 1999). Too shallow sea can also limit the extent of planktonic foraminifera. The vertical range of planktonic foraminifera, related to their ontogeny, depends on water depth and each species has its own bathymetric restrictions (Bé, 1977; Bailey and Hart, 1979; Caron and Homewood, 1983; Hemleben et al., 1989; Premoli Silva and Sitter, 1999).

During the Late Cretaceous, the area studied was a part of the European epicontinental sea and belonged to the Transitional Foraminiferal Province (Pożarska and Peryt, 1979). This palaeogeographic location of the area and Late Cretaceous eustatic changes determined the diversity and taxonomic composition of its planktonic foraminiferal assemblages (Walaszczyk and Peryt, 1992; Dubicka and Peryt, 2012a). In general, these assemblages are taxonomically less diverse and contain fewer stratigraphically important forms than low-latitude assemblages, e.g. Tethyan. Unfortunately, the standard planktonic foraminiferal zonations (Hardenbol et al., 1998) are mainly based on low-latitude species of the family Globotruncanidae. Accordingly, these zonations are applicable in European epicontinental basins only in some intervals, e.g. in the Cenomanian, and are less useful in others, e.g. in the Campanian and Maastrichtian. As a result, some local zonations were established (e.g., Peryt, 1980; Dubicka and Peryt, 2012a).

The benthic foraminifera, which are often regarded as less useful in stratigraphy, can be very helpful, and often even more so than planktonic foraminifera, in the biostratigraphy of the European epicontinental Upper Cretaceous. In general, during the Late Cretaceous benthic foraminiferal assemblages were almost uniform throughout the European epicontinental basin and evolved and diversified comparatively quickly. Accordingly,
they serve as a good tool for stratigraphy and regional/interregional correlations across Europe (e.g., Hiltermann, 1952; Hofker, 1952; Akimets, 1961; Koch, 1977; Rozumeiko, 1978; Halszkiwes, 1986; Bailey et al., 2009; Wilkinson, 2011; Dubicka and Peryt, 2014).

This work constitutes a part and continuation of the long-term and multi-disciplinary study on the stratigraphy of the Campanian–Maastrichtian transition of the Middle Vistula River section (see details in Walaszczyk, 2012). We describe planktonic as well as benthic foraminiferal bioevents which seem to have supraregional applications and compare them with the same events of other regions with well-established macrofaunal biostratigraphy.

GEOLoGICAL SETTING

The Upper Campanian–lowermost Maastrichtian sediments examined in this study are represented by a set of natural and artificial exposures scattered along the Middle Vistula River valley in central Poland. The study area belongs structurally to the Border Synclinorium (Kutek and Glazek, 1972; Pożaryski, 1997; Świdrowska, 2007; Voigt et al., 2008), i.e., to the Kościeryzna–Pulawy Synclinorium of the most recent structural scheme (Żelaźniewicz et al., 2011). The interval studied is exposed between the villages of Dorotka, Dzuriłków and Kłudziej on the western bank of the river, and between the villages of Łopoczno and Kamień, on its eastern bank (Fig. 1 and Table 1).

The upper Campanian–lowermost Maastrichtian succession is ca. 130 m thick and comprises mainly opoka (= siliceous lime stone) (Walaszczyk, 2004). Walaszczyk (2004) distinguished five local lithostratigraphic units: Dorotka, Piotrawin and Dzuriłków opoka (the intervals with white, highly fossiliferous opoka) and the Soliec and Wola Pawłowka opoka (the intervals with marly, brownish-grey, less fossiliferous opoka).

The studied interval represents Pożaryski’s (1938) local zones from n to v and corresponds to Kongiel’s (1962) Campanian α, β and γ zones and an unnamed interval between the Campanian γ Zone and the Maastrichtian α Zone. The following cephalopod zones in ascending order were distinguished in this interval by Błaszkiewicz (1986): Bostrychoceas polyplocum, Cirroceras doneizianum, Nostoceras vistulae, Bellemnella lanceolata lanceolata and Bellemnella occidentalis. Błaszkiewicz (1986) also placed the Nostoceras vistulae Zone with the Nostoceras pozarskii (= N. hyatti) Zone. Walaszczyk (2004) in the same interval distinguished eight ineramicid bivalve zones in ascending order: Catarceramus subcompressus, “Ineramus” tenuilineatus, Sphaeroeramus pertenuiformis, “Ineramus” altus, “Ineramus” inkemansensis, Trochiceramus costaeus, “Ineramus” redbirdensis, and Endococsea typica. Pożaryski (1938) placed the Campanian/Maastrichtian (CM) boundary between his units r and s. Kongiel (1962) shifted its position to the mid of unit t, and subsequently both Pożaryski (1966) and Błaszkiewicz (1966, 1980) accepted this revised position of the CM boundary (Fig. 2).

After the ratification of the Campanian/Maastrichtian stage boundary at Tercis les Bains (Odin, 2001), the former lowest Maastrichtian beleninite zone in the Boreal Province, i.e., the Bellemnella lanceolata Zone, falls within the uppermost Campanian (Christensen et al., 2000; Niebuhr et al., 2011; Keutgen et al., 2012; Machalski, 2012; Remin, 2012). According to Walaszczyk (2004), the CM boundary (as defined in the stratotype section at Tercis) in the Middle Vistula River valley falls in the Kłudziej sections in the upper part of the “Ineramus redbirdensis” Zone, which corresponds to the base of the Bellemnella occidentalis Zone distinguished by Błaszkiewicz (1980), i.e. at the top of Pożaryski’s (1938) unit v. Remin (2012) put the Campanian/Maastrichtian boundary at the base of the Bellemnella obtusa–B. vistulensis zone.

Based on calcareous non fossils, Gażdzicka (1978) included the Upper Campanian–lowermost Maastrichtian strata of the Middle Vistula River section into the Tetralithus (= Ceratolitoides) aculeus Zone, while Peryt (1980) subdivided this interval into two planktonic foraminiferal zones: Globigerinelloides multispinus and Rugoglobigerina pennyi (lower part).

Burnett et al. (1992) assigned strata from the Piotrawin Quarry represented by the Nostoceras pozarskii (= N. hyatti) Zone of Błaszkiewicz (1980) or the “Ineramus” altus and “Ineramus” inkemansensis ineramicid zones of Walaszczyk (2004) to non fossil Subzone 22C. Peryt (2000) recognized in this profile the following zones: the miliaris/navarroana Partial Range Zone (upper part), the navarroana/cristata Partial Range Zone, the poząrski/hiltermanni Concurrent Range Zone and the decurrers Interval Zone (lower part). I.e. benthic foraminiferal zones established by Schöpfel (1990) in the upper Campanian of the Lägerdorf section in northern Germany. Dubicka and Peryt (2012a) included the interval comprising the Piotrawin, Raj N, Kłudziej and Dzuriłków sections, i.e. the “I.” altus, “I.” inkemansensis, T. costaeus, “I.” redbirdensis and Endococsea typica ineramicid zones, in their foraminiferal zones I to IV.

MATERIAL AND METHODS

Ninety-seven samples from the upper Campanian–lowermost Maastrichtian of 17 natural and artificial outcrops from the Middle Vistula River section were investigated. Washed residues for foraminiferal study were obtained from the rocks by disaggregation using Na2SO4 and sieving into >63 μm size fraction. The classification scheme used follows Caron (1985), Loeblich and Tappan (1987) and Pawłowski et al. (2013).

Since the present paper concerns the biostratigraphy we focused on the most stratigraphically important foraminifera. We tracked mainly the ranges of planktonic foraminifera belonging to the genera Globoturricula and Rugoglobigerina, and those of the benthic genera Globorotalites, Gavelinella, Angulogavelinella, Bolivina, Bolivinoides and Neoflabellina. Representatives of these genera which have their first FO or last occurrences (LO) in the studied interval are discussed and their vertical ranges are compared to their stratigraphical ranges across Europe. The material was studied in detail and documented using a Philips XL20 SEM (Figs. 3 and 4). The morphological features crucial for diagnosis of the foraminifera studied are presented in the chapter “Taxonomy and comments”.

FORAMINIFERAL SUCCESSION

PLANKTONIC FORAMINIFERA

In the succession studied, planktonic taxa compose from a few percent to almost 60% of the foraminiferal assemblages (cf. Peryt, 1980, 2000; Dubicka and Peryt, 2012a). More than 30 species of planktonic foraminifera are recorded (cf. Peryt, 1980). Their ranges, particularly their first and last occurrences, were strongly influenced by palaeoenvironmental changes. It is therefore impossible to apply the standard planktonic foraminiferal zonation for subdivision of this succession. Peryt (1980) included the studied interval in the Globigerinelloides
Fig. 1A – geological sketch map of the Upper Campanian through the Lower Maastrichtian in the Middle Vistula (Wisła) River valley section, central Poland (after Walaszczyk, 2004); B – geological pre-Cenozoic sketch map of Poland (after Pożaryski, 1974; Dadlez et al., 2002; Narkiewicz and Dadlez, 2008; Żelaźniewicz et al., 2011; simplified)
### Fig. 2. History of stratigraphical studies of the Upper Campanian through the Lower Maastrichtian in the Middle Vistula River valley section, central Poland

<table>
<thead>
<tr>
<th>CAMPANIAN</th>
<th>MAASTRICHTIAN</th>
<th>Stage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper</td>
<td>Lower</td>
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<td>Substage</td>
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#### Foraminiferal bioevents in the Upper Campanian to lowest Maastrichtian of the Middle Vistula River section, Poland

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</tr>
</tbody>
</table>

- **Belennitella langei**
  - **Neplocaephanis constrictus vulgaris**
  - **Belennitella lanceolata**
  - Pozaryszki (1986)

- **Bosicycloceae polyptilum**
  - **Cimoceras dorexanum et subsp. Cimoceras sp. nov.**
  - **Nostoceras vistulae**
  - **Acanthosphaenites quadripinclus**
  - **Pachydiscus neubergicus neubergicus subsp. nov.**
  - **Belennitella lanceolata lanceolata**
  - **Belemnella occidentalis**
  - Blasskiwicz (1980)

- **Bosicycloceae polyptilum**
  - **Dialymoceras doneastrum**
  - **Nostoceras pozaryski**
  - **N. vistulae**
  - **Belennitella lanceolata lanceolata**
  - **Belemnella occidentalis**
  - Blasskiwicz (1980)

- **Tetralithus ovatus**
  - Gałdzicka (1979)

- **Globigerinoides multispinus**
  - Rugoglobigerina pennyi
  - Peryt (1980)

- **ZGC**
  - Bumett et al. (1992)

- **miliaris inornata**
  - **nasutum cristata**
  - **patersoni decurrens**
  - Peryt (2000)

- **Dubicka and Peryt (2012a)**

<table>
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<tr>
<td>Substage</td>
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</tbody>
</table>

- **Callocecamus subcompressus**
  - **Inoceramus tenellineatus**
  - **Sphaeroceras pertenuiformis**
  - **Inoceramus**
  - **Inoceramus inornatus anatolianus**
  - **Trochoceras costaeus**
  - **Inoceramus**
  - **Inoceramus redorbedensis**
  - **Endoceras typica**
  - Walczyszyn (2004)

- **Belennitella zones**
  - **Belennitella lanceolata**
  - **Belennitella inflate**
  - **Belennitella vistulensis**
  - **Belennitella sp. G**
  - **Belennitella sp. F**
  - Remin (2012)

- **Belennitella najdii**
  - **Belennitella posterior**
  - **Belennitella minor i**
  - **Belennitella minor ii**
  - **Belennitella vistulensis**
  - **Belennitella sp. G**
  - **Belennitella sp. F**
  - Remin (2015)
**Table 1**

<table>
<thead>
<tr>
<th>Name</th>
<th>Exposure</th>
<th>Location</th>
<th>Exposed strata</th>
<th>Inoceramid bivalve and cephalopod biostratigraphy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dziurków</td>
<td>small active quarry</td>
<td>eastern side of the village of Dziurków</td>
<td>opoka (12 m)</td>
<td><em>Endocosta typica</em> Zone; <em>upper Belemella occidentalis</em> Zone; <em>Belemella obtusa</em> Zone</td>
</tr>
<tr>
<td>Kludzie North</td>
<td>small natural outcrop</td>
<td>western bank of the Vistula, about 30 m north of the Kludzie ferry stop</td>
<td>opoka (9 m) with the marl layer about 6 m above the Vistula level</td>
<td><em>&quot;Inoceramus&quot; redbirdensis</em> Zone; <em>upper Belemella lanceolata</em> and lower <em>B. occidentalis</em> zones; <em>upper Belemella inflata</em> and lower <em>B. vistulensis</em> zones</td>
</tr>
<tr>
<td>Kludzie South</td>
<td>small natural outcrop</td>
<td>western bank of the Vistula, about 100 m south of the Kludzie ferry stop</td>
<td>opoka (18 m) with marl layer in the middle part</td>
<td><em>&quot;Inoceramus&quot; redbirdensis</em> and <em>lowermost E. typica</em> Zone; <em>upper Belemella lanceolata</em> and lower <em>B. occidentalis</em> zones; <em>upper Belemella inflata</em> and <em>B. vistulensis</em> zones</td>
</tr>
<tr>
<td>Solec</td>
<td>small natural outcrop</td>
<td>western part of the town of Solec</td>
<td>marly opoka (14 m)</td>
<td><em>upper Trochoceramus costaeus</em> and <em>lower &quot;I.&quot; redbirdensis</em> zones; <em>Belemella lanceolata</em> Zone; <em>Belemella inflata</em> Zone</td>
</tr>
<tr>
<td>Raj North</td>
<td>small quarry</td>
<td>southern bank of the Kreppanka River, a small tributary of the Vistula river</td>
<td>marly opoka (9 m)</td>
<td><em>upper Trochoceramus costaeus</em> and <em>lower &quot;I.&quot; redbirdensis</em> Zone; <em>Belemella lanceolata</em> Zone; <em>lower B. inflata</em> Zone</td>
</tr>
<tr>
<td>Kamieńi</td>
<td>small natural outcrop</td>
<td>exposure in the road escarpment</td>
<td>opoka</td>
<td><em>base of the Trochoceramus costaeus</em> Zone; <em>base of the Belemella lanceolata</em> Zone</td>
</tr>
<tr>
<td>Piotrawin</td>
<td>large abandoned quarry with three exploitation levels</td>
<td>eastern bank of the Vistula, about 500 m south of the Piotrawin village</td>
<td>opoka (approx. 30 m)</td>
<td>*&quot;I&quot; altus and &quot;I&quot; inkermanensis zones; Nostoceras pozaryskii (= <em>N. hyatti</em>) Zone</td>
</tr>
<tr>
<td>Raj</td>
<td>small abandoned quarry</td>
<td>100 m south of the village of Raj</td>
<td>opoka (7 m)</td>
<td>*&quot;I&quot; inkermanensis and <em>Nostoceras pozaryskii</em> (= <em>N. hyatti</em>) zones</td>
</tr>
<tr>
<td>Sadkowice North</td>
<td>small abandoned quarry</td>
<td>western bank of the Vistula river, in the northern part of the village</td>
<td>opoka (7 m)</td>
<td>*middle &quot;I&quot; inkermanensis Zone; <em>upper Nostoceras pozaryskii</em> (= <em>N. hyatti</em>) Zone</td>
</tr>
<tr>
<td>Sadkowice Quarry</td>
<td>small abandoned quarry</td>
<td>about 100 m west of the main cross-road in the village</td>
<td>opoka (10 m)</td>
<td>*lower &quot;I&quot; inkermanensis Zone; <em>upper Nostoceras pozaryskii</em> (= <em>N. hyatti</em>) Zone</td>
</tr>
<tr>
<td>Pawłowice North</td>
<td>small natural outcrop</td>
<td>western bank of the Vistula river, about 1 km north of the main cross-road in the village</td>
<td>opoka (6 m)</td>
<td>*upper &quot;I&quot; altus Zone; <em>lower Nostoceras pozaryskii</em> (= <em>N. hyatti</em>) Zone</td>
</tr>
<tr>
<td>Pawłowice Cemetery</td>
<td>small natural outcrop</td>
<td>exposure at the northern end of the village cemetery</td>
<td>opoka (5 m)</td>
<td>*lower &quot;I&quot; altus Zone; <em>lower Nostoceras pozaryskii</em> (= <em>N. hyatti</em>) Zone</td>
</tr>
<tr>
<td>Łopoczno</td>
<td>small natural outcrop</td>
<td>exposure in the eastern bank of the Vistula river</td>
<td>opoka (5 m)</td>
<td>*upper <em>Sphaeroeramus pertenuiformis</em> Zone; <em>upper Didymoceras donezianum</em> Zone</td>
</tr>
<tr>
<td>Wola Pawłowska</td>
<td>small operating quarry</td>
<td>exposure in the northern bank of the Kamienna river, a tributary of the Vistula, about 850 m south of the village bridge</td>
<td>marly opoka (7 m)</td>
<td>*lower <em>Sphaeroeramus pertenuiformis</em> Zone; <em>upper Didymoceras donezianum</em> Zone</td>
</tr>
<tr>
<td>Ciszycy Górna</td>
<td>small natural outcrop</td>
<td>exposure in the western bank of the Vistula river</td>
<td>opoka (6 m)</td>
<td>*&quot;I&quot; tentulineatus Zone; <em>lower Didymoceras donezianum Zone</em></td>
</tr>
<tr>
<td>Kolonia Ciszycy</td>
<td>small natural outcrop</td>
<td>exposure in the western bank of the Vistula river, beside the Lesne Chalupy-Tartów road</td>
<td>opoka (5 m)</td>
<td>*lower &quot;I&quot; tentulineatus Zone; <em>lower Didymoceras donezianum Zone</em></td>
</tr>
<tr>
<td>Dorotka</td>
<td>small abandoned quarry</td>
<td>exposure in the western bank of the Vistula river, 50 m north of the main road in the village</td>
<td>opoka (7 m)</td>
<td><em>Cataceramus subcompressus</em> Zone; <em>Bostrychoferus polyplacum</em> Zone</td>
</tr>
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*multispinus* and the *Rugoglobigerina pennyi* zones of the local planktonic foraminiferan zonation. In the lower part of the interval studied (Cataceramus subcompressus, "Inoceramus" tentulineatus and lower part of the *Sphaeroeramus pertenuiformis* inoceramid zone), the planktonic foraminiferan assemblages show high diversity with common deep-water planktonic foraminifera: *Contusotruncana fornicata*, *C. plummerae* (Fig. 3Aa–Ab), *C. patelliformis*, *Globotruncana ventricosa* (Fig. 3Ba–Bb), *G. rugosa* (Fig. 3Ca–Cb), *G. cf. aegyptiaca*, *G. mariae*, *G. bulloides*, *G. lineolata*. *Archeoglobigerina blowi*, *A. cretacea* and *Pseudotextularia nuttalli* (Fig. 3Ha–Hb) are also present in this interval. In the "Inoceramus" altus Zone, globotruncanids disappear almost completely. The interval comprising the "Inoceramus" altus, "I." inkermanensis, *Trochoceramus costaeus* and "I." redbirdensis inoceramid zones is characterized by low diversity planktonic foraminiferan assemblages dominated by *Heterohelix* and *Globigerinelloides*. This taxonomic impoverishment probably
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Fig. 3. Selection of significant benthic and planktonic foraminifera from the studied interval

Aa–Ab – Contusotruncanaplummerae (Gandolfi), Cisyca Górna, sample 1; Ba–Bb – Globotruncanaventricosa (White), Cisyca Górna, sample 4; Ca–Cb – Globotruncanarugosa (Marie), Wołapawłowska, sample 1; Da–Db – Rugoglobigerinahexacamerata Brönnimann, Kudzie N, sample 3; Ea–Eb – Rugoglobigerinarugosa (Plummer), Kudzie N, sample 3; Fa–Fb – Rugoglobigerinamilamensis Smith and Pessagno, Kudzie N, sample 3; Ga–Gb – Rugoglobigerinapennyi Brönnimann, Kudzie N, sample 3; Ha–Hb – Pseudotextularia nuttalli (Voorwijk), Cisyca Górna, sample 4; I – Bolivinadecurrens (Ehrenberg); I – Raj N, sample 2, J – Sadowicew, sample 1; K–M – Bolivina incrassata Reuss: K – Kudzie, sample 3, L – Raj, sample 5, M – Raj, sample 2; N – Neoflabellinaprareticulata Hiltermann, Piotrawin, sample 5; O – Neoflabellinareticulata (Reuss), Kudzie, sample 3; P – Bolivinoides miliaris Hiltermann et Koch, Dorotka, sample 1; Q, R – Bolivinoides sp. – transitional form from Bolivinoides miliaris Hiltermann et Koch to B. draco (Marsson), Kudzie N, sample 3; scale bars – 200 μm
Fig. 4. Selection of significant benthic foraminifera from the studied interval

*Aa–Ac, Ca–Cc* – *Globorotalites emdyensis* Vasilyenko, Cisyca Górna, sample 1; *Da–Dc* – *Globorotalites michelinianus* (d’Orbigny), Wola Pawłowska, sample 3; *Ba–Bb, F* – *Osangularia navarroana* (Cushman), Płotrawin, sample 4; *Ea–Ec* – *Angulogavelinella gracilis* (Marsson), Kludzie N, sample 14; *Ga–Gc* – *Gavelinella clementiana* (d’Orbigny), Dorotka, sample 1; *Ha–Hc* – *Gavelinella monterelensis* (Marie), Dorotka, sample 1; scale bars – 200 µm
reflects the latest Campanian–earliest Maastrichtian eustatic sea level fall (Dubicka and Peryt, 2012a). In the uppermost Campanian Rugoglobigerina rugosa appears. The lowest occurrence of the species is noted in the Raj North section, i.e. in the lower part of the Bellemnella lanceolata lanceolata Zone sensu Błaszkiewicz (1980) and at the base of the Bellemnella inflata Zone (Remin, 2012). At approximately this level, i.e. just below the traditional B. lanceolata Zone, the FO of Rugoglobigerina was reported from Norfolk, England (Hart et al., 1989; Hart and Świecki, 2003). An abundant and taxonomically more diverse occurrence of Rugoglobigerina begins at the boundary marly at Kludzie, i.e. within the “Inoceramus redbiriensis” inoceramid Zone. Rugoglobigerina is represented there by the following species: R. pennyi, R. milamensis, R. hexacamerata and R. rugosa. The predominance of Rugoglobigerina in planktonic foraminiferal assemblages is commonly noted in the Lower Maastrichtian of Poland, Ukraine (Dubicka and Peryt, 2012a) and Russia (Saratov Region – Offerev et al., 2007, and northwestern Rostov Region – Benyamovski et al., 2012). In the Zumaia section in northern Spain (Pérez-Rodríguez et al., 2012) R. rugosa, R. hexacamerata and R. pennyi occur below the Campanian/Maastrichtian boundary i.e. within the Rugoglobigerina rotundata Zone, below the base of the Pachydiscus neubergicus ammonite Zone. Accordingly, the appearance of Rugoglobigerina in the Vistula River section is an only local event and can be applied in only temperate regions.

Rugoglobigerina scotti was described from the Campanian/Maastrichtian boundary in the Tercis les Bains section (Arz and Molina, 2001). Odin et al. (2001) considered this species to be Rugoglobigerina cf. scotti (a transitional form) which cannot be useful for identifying the Campanian/Maastrichtian boundary. At Zumaia “true” Rugoglobigerina scotti has its lowest occurrence in the middle part of the Abathomphalus mayaroensis Zone in the uppermost Maastrichtian (Pérez-Rodríguez et al., 2012).

**BENTHIC FORAMINIFERA**

Based on the study of stratigraphically relevant benthic foraminiferal taxa we recognized thirteen foraminiferal bioevents. These events are discussed below in ascending stratigraphic order.

The LO of Gavelinella clementiana is recorded in the Dorotka outcrop, i.e. in the Cataceras subcompressus inoceramid Zone and the Bostychoceras polytocum ammonite Zone. The LO of the species in Kronsmoor in NW Germany was recorded much higher, i.e. in the navarroana/cristata Zone, in the lower Micraster grimmensis/Cardiaster granulosus Zone (Schönfeld, 1990). In eastern England G. clementiana disappears within the interval of the co-occurrence of Globorotalites hiltermanni (= G. emdyensis) and Bolivina incrassata (Hart et al., 1989), which is probably later than in the Middle Vistula River section. In the Tercis section, the highest occurrence of G. clementiana is recorded just above the Campanian/Maastrichtian boundary (Odin and Lamurelle, 2001), this being much higher than in all of the above-mentioned zones. Thus the LO of G. clementiana is clearly diachronous in epicontinental Cretaceous of Europe, which was also recognized by Watkins and Veikamp (1994). It seems that G. clementiana was very sensitive to environmental changes, which precludes its use in supra-regional correlations. In the Dorotka section, we also noticed the occurrence of Globorotalites emdyensis (= G. hiltermanni). Since this species has not been recorded in the stratigraphically lower Inoceramus azerbaydjanensis–Inoceramus vorhelmensis inoceramid Zone of the Polish Lowland (Dubicka, 2015), its first appearance seems to be in the Cataceras subcompressus inoceramid Zone and the Bostychoceras polytocum ammonite Zone. This position corresponds to the FO of Globorotalites emdyensis (= G. hiltermanni) recorded in the Lägerdorf-Kronsmoor succession, i.e. in the middle part of the Bostychoceras polytocum Zone.

In the lower part of the “Inoceramus” tenuilineatus and Didymoceras donezianum zones in the Ciszyca Kolonia section Bolivina incrassata and Bolivinoides miliaris have been recorded. Their actual FOs are probably stratigraphically lower than that, as we found these taxa in K. Pożaryska’s archive sample named “Dorotka North”, located in the northern part of the village of Dorotka. Similarly, in the Lägerdorf-Kronsmoor succession the FOs of these two taxa are placed very close to each other within a few metres, just below and above the F100 horizon and slightly above the FO of Globorotalites hiltermanni (Schönfeld, 1990). They are placed in the Bostychoceras polytocum Zone sensu Schulz et al. (1984). In eastern England, as well as in the southern North Sea Basin, the lowest records of all these species are also stratigraphically very close to each other, in the upper part of the traditional Bellemnita mucronata Zone (Hart et al., 1989; Hart and Świecki, 2003). Accordingly, the FOs of Globorotalites emdyensis (= G. hiltermanni), Bolivina incrassata and Bolivinoides miliaris appear to be stratigraphically relevant for correlation across Europe.

The LO of Globorotalites michelinianus is recorded in the Ciszyca Górna succession, i.e. in the Didymoceras donezianum ammonite Zone and in the “Inoceramus” tenuilineatus inoceramid Zone (Fig. 5). Hart et al. (1989) noted the LO of G. michelinianus in eastern England in the upper part of the traditional Bellemnita mucronata Zone within the lower part of the ranges of G. emdyensis (= G. hiltermanni) and Bolivinoides miliaris, as observed in the section studied. Thus, this foraminiferal event occurs in a similar stratigraphical position in both central and western parts of Europe.

The FO of Osangrailia navarroana is recorded in the upper part of the Wola Pawłowska section, in the Sphaeroceramus pertenuiformis inoceramid Zone. At Kronsmoor, this species appears at 226.10 m, defining the base of the navarroana/oristata Zone. It occurs in the uppermost part of the Bellemnita langei Zone and just below the FO of Angulogavelinella gracilis. Therefore, the first appearances of O. navarroana in the Middle Vistula River section and in Kronsmoor seem to occur in a similar stratigraphical position.

The temporary disappearance of Gavelinella monterelenis was recorded in the lowest part of the Pawłowice Cemetery section. A morphological equivalent of G. monterelenis were also observed in a Middle Maastrichtian interval of the Middle Vistula River section (Dubicka and Peryt, 2012b), as well as in the Vlijmen Member in Belgium (Robaszynski et al., 1985). The disappearance of G. monterelenis (= Brotenella monterelenis) were recorded in an approximately similar position in the Vishnevce section, Saratov Region, Russia (Offerev et al., 2007). The event is located there in the Nalitovo Formation, above the FOs of Bellemnita langei langei, B. langei najdini and Bellemnita licharevi, and below the FO of Bellemnella lanceolata. Additionally, it is placed slightly below the FO of Globorotalites emdyensis (= G. hiltermanni), as in the Middle Vistula River section.

In the lowest part of the Pawłowice Cemetery section the first record of a “true” Angulogavelinella gracilis is observed. Early forms of A. gracilis which occur throughout the Łopoczno section (Sphaeroceramus pertenuiformis inoceramid Zone) are
Fig. 5. Geological columns, stratigraphy and correlations of the sections studied.
characterized by a test with a flat trochospiral side. In the Wola Pawłowska section there is an absence of all morphotypes of A. gracilis. According to these foraminiferal data, the Wola Pawłowska section should be shifted slightly lower than as indicated by Walaszczyk (2004). i.e. these two successions probably do not correlate. The interval with the co-occurrence of G. monterelensis, “true” A. gracilis and Neoflabellina praereticulata is represented in the Middle Vistula River section only in the lower part of the Pawłowie Cemetery succession. It is better exposed in the Miechów Synclinorium in southern Poland. A precise stratigraphical position of the lowest record of A. gracilis (= A. bettensstaedti) was determined by Schönfeld (1990) at Kronsmoor, northwestern Germany where the species first appears at 231.30 m in the lower part of the navarroana/cristata Zone, close to the lower boundary of the Belemnitella langei Zone and just below the LO of granulosus. These taxa also occur throughout the B. lanceolata Zone, thus in a similar stratigraphical position to the inferred base of the traditional Belemnella lanceolata Zone (Hart et al., 1989). Recent research has shown that the FO of N. reticulata is located beneath a marl seam (Sidestrand Martl), a short distance below the entry of a Belemnella assemblage belonging to Remin’s inflata Zone (see Mortimore et al., 2001, fig. 4.32; Wood pers.comm., 2015). In the Kronsmoor section, it appears at the 254.90 m level (Schönfeld, 1990), close to level mb 605, which according to Remin’s belemnite zonal scheme (Remin in Niebuhr et al., 2011) is also located within the highest Upper Campanian Belemnella inflata Zone. Figure 7 of Niebuhr et al. (2011), shows erroneously the FO of N. reticulata at F600. In eastern Europe, the FO of N. reticulata in the Belemnella lanceolata Zone was also recorded in the Vishnevoe section (Saratov Region – Olferev et al., 2007). The event therefore seems to be an important marker for stratigraphical correlation across Europe.

In conclusion, it is very likely that, except for the FO of Gavelinella clementiana and FO of Neoflabellina praereticulata, all of the other discussed benthic foraminiferal events are isochronous between western and central European basins. Thus they can serve as useful chronostratigraphic markers across Europe.

**TAXONOMIC COMMENTS**

Only the occurrences within the Middle Vistula River section are given in the descriptions which follow.

Superfamily Globotruncanacea Brotzen, 1942
Family Rugoglobigerinidae Subbotina, 1959
Genus Rugoglobigerina Brönnimann, 1952
Rugoglobigerina hexacamerata Brönnimann, 1952 (Fig. 3Da–Db)

Rugoglobigerina reicheli hexacamerata – Brönnimann, 1952: 23–25, pl. 2, figs. 10–12, fig. 8a–m.
Rugoglobigerina hexacamerata Brönnimann – Pessagno, 1967: 364–365, pl. 74, fig. 4, pl. 91, figs. 5–7.
Rugoglobigerina hexacamerata Brönnimann – Peryt, 1980: 84–85, pl. 22, figs. 6, 7.
Rugoglobigerina hexacamerata Brönnimann – Robaszynski et al., 1984; 282, pl. 49, fig. 8.

Description – Test with very low to flat trochospire; equatorial periphery circular, lobate; axial periphery rounded; the last whor consists of 6 chambers increasing very slowly in size as added, ultimate chamber very often smaller than penultimate one; wall covered by meridionally arranged rugosities except terminal 2 or 3 chambers which are commonly smooth; spiral sutures depressed, radial; umbilical sutures radial to slightly curved; umbilicus small, deep; primary aperture umbilical.

Remarks – It differs from R. pennyi in having a flat spiral side, six chambers increasing very slowly in size in the last whor and a very low height/diameter ratio.

Occurrence – First appears in the Kudzie section in the “Inoceramus” redbirdensis inoceramid Zone and ranges to
the top of the analysed part of the Middle Vistula River succession.

Rugoglobigerina milamensis Smith and Pessagno, 1973 (Fig. 3Fa–Fb)

Rugoglobigerina milamensis Smith and Pessagno – Robaszynski et al., 1984: 284, pl. 50, fig. 3.
Rugoglobigerina milamensis Smith and Pessagno – Peryt and Dubicka, 2009, figs. 4, 7a–c, 9a–c.

Description. – Test moderately trochospiral; equatorial periphery subcircular, lobate; chambers spherical to subspherical, slightly elongated axially in apertural view; 5 to 6 chambers in the last whorl increasing slowly in size; wall heavily ornamented with rugosities and costellae but ornamentation not clearly developed in a meridional pattern; primary aperture umbilical.

Remarks. – R. milamensis differs from R. pennyi in having a very highly convex spiral side.

Occurrence. – First appears in the Kludzie section in the “Inoceramus redbirdensis” inoceramid Zone and ranges to the top of the analysed part of the Middle Vistula River succession.

Rugoglobigerina pennyi Brönnimann, 1952 (Fig. 3Ga–Gb)

Rugoglobigerina pennyi – Brönnimann, 1952: 34, pl. 4, figs. 1–3, figs 14a–c, d–f, g–i.
Rugoglobigerina pennyi Brönnimann – Peryt, 1980: 86–87, pl. 12, fig. 6, pl. 22, figs. 10, 11.
Rugoglobigerina pennyi Brönnimann – Robaszynski et al., 1984: 285, pl. 50, fig. 1.
Rugoglobigerina pennyi Brönnimann – Peryt and Dubicka, 2009, fig. 4: 11a–c.

Description. – Test low trochospiral, equatorial periphery lobate; 5 to 6 spherical chambers in the final whorl increasing gently in size; wall covered by meridionally arranged rugosities; sutures depressed, radial; primary aperture umbilical.

Occurrence. – First appears in the Kludzie section in the “Inoceramus redbirdensis” inoceramid Zone and ranges to the top of the analysed part of the Middle Vistula River succession.

Rugoglobigerina rugosa (Plummer, 1926) (Fig. 3Ea–Eb)

Globigerina rugosa n.sp. – Plummer, 1926: 38, pl. 2, fig. 10a–d (fide Ellis et Messina, Cat. of Foram.).
Rugoglobigerina rugosa (Plummer) – Peryt, 1980: 87, pl. 22, figs. 2, 3, 4, 8.
Rugoglobigerina rugosa (Plummer) – Hart et al., 1981: 218, pl. 7.23, figs. 7–9.
Rugoglobigerina rugosa (Plummer) – Robaszynski et al., 1984: 288, pl. 49, figs. 4a–c, 6a–c.
Rugoglobigerina rugosa (Plummer) – Gawor-Biedowa, 1992: 92, pl. 17, figs. 8, 9.

Description. – Test trochothorial, biconvex, spiral side moderately convex; equatorial periphery lobate, axial periphery broadly rounded; 4 to 5 globular chambers in the final whorl, increasing sharply in size as added; wall covered by meridionally arranged rugosities; umbilicus large, deep; primary aperture umbilical.

Occurrence. – First appears in the Raj North and Solac sections in the Trochoeramus costaeus inoceramid Zone and ranges to the top of the analysed succession of the Middle Vistula River section.

Superfamily Nodosariacea Ehrenberg, 1838
Family Vaginulinidae Reuss, 1860
Genus Neoflabellina Bartenstein, 1948
Neoflabellina praereticulata Hiltermann, 1952 (Fig. 3N)

Neoflabellina praereticulata n. sp. – Hiltermann, 1952: 53, text-fig. 3.37.
Neoflabellina praereticulata Hiltermann – Hiltermann and Koch, 1962: 308, pl. 50, fig. 12.
Neoflabellina praereticulata Hiltermann – Hart et al., 1981: 212, pl. 7.20, fig. 2.
Neoflabellina praereticulata Hiltermann – Robaszynski et al., 1985, pl. 5, fig. 2.
Neoflabellina reticulata (Reuss) – Gawor-Biedowa, 1992: 58–59, pl. 8, fig. 11.
Neoflabellina reticulata (Reuss) – Peryt, 2000, pl. 1, fig. 13.

Description. – Test large, palmate to deltoid in outline with parallel and flat sides; early chambers in a planispiral coil, rapidly becoming uniserial with clearly marked longitudinal symmetry; sutures raised and distinct; numerous short ridges between sutures; aperture terminal, radiate, on the neck.

Remarks. – N. praereticulata differs from N. reticulata in lacking connections between sutures and ridges occurring in the test surface resulting in lack of checked ornamentation.

Occurrence. – First appears at Łopoczno in the Sphaeroceramus pertenuiformis inoceramid Zone and ranges to the top of the analysed succession of the Middle Vistula River section.

Neoflabellina reticulata (Reuss, 1851) (Fig. 3O)

Flabellina reiculata n. sp. – Reuss, 1851: 30, pl. 1, figs. 22a–c (fide Ellis et Messina, Cat. of Foram.)
*Neoflabellina reticulata* (Reuss) – Hiltermann and Koch, 1962: 309, pl. 50, figs. 13, 14.
*Neoflabellina reticulata* (Reuss) – Koch, 1977: 58, pl. 14, figs. 9, 10.
*Neoflabellina reticulata* (Reuss) – Hart et al., 1981: 212, pl. 7.20, fig. 3.
*Neoflabellina reticulata* (Reuss) – Robaszynski et al., 1985, pl. 5, fig. 3.
*Neoflabellina reticulata* (Reuss) – Peryt, 1988, pl. 11.
*Neoflabellina reticulata* (Reuss) – Schönfeld, 1990: 74–75, pl. 2, fig. 12.
*Neoflabellina reticulata* (Reuss) – Dubicka and Peryt, 2011, fig. 5W.

**Description.** – Test large, palmate to deltoid in outline with parallel and flat sides; early chambers in a planispiral coil, rapidly becoming uniserial with clearly marked longitudinal symmetry; distinct and raised sutures and numerous short ridges extending between sutures and approximately perpendicular to them, forming characteristic reticulate ornamentation; aperture terminal, radiate, on the neck.

**Remarks.** – *N. reticulata* differs from *N. praereticulata* in possessing short ridges connected with the sutures, resulting in reticulate ornamentation.

**Occurrence.** – First appears at the base of the Kludzie section in the *Belemnella inflata* Zone and ranges to the top of the analysed part of the succession.

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Superfamily Bolivinacea Glaessner, 1937
Family Bolivinidae Loeblich and Tappan, 1964
Genus *Bolivina* d’Orbigny, 1839
*Bolivina decurrens* (Ehrenberg, 1854)  
(Fig. 3I, J)

*Grammostomum? decurrens* – Ehrenberg: 22, pl. 30, fig. 17 (*fide* Ellis et Messina, Cat. of Foram.).
*Bolivina decurrens* (Ehrenberg) – Hofker, 1966: 39, pl. 5, fig. 40; p. 59, pl. 10, figs. 76, 102; p. 73, pl. 12, fig. 26.
*Bolivina decurrens* (Ehrenberg) – Peryt, 1988, pl. 2, fig. 14.
*Coryphostoma decurrens* (Ehrenberg) – Peryt, 2000, pl. 1, figs. 6, 7.
*Bolivina decurrens* (Ehrenberg) – Dubicka and Peryt, 2012a, fig. 4A–C.

**Description.** – Test biserial, free, elongate and compressed; outline view of the test distinctly indented; margins acute and spinose. The aperture sub-terminal, elongated elliptical slit.

**Occurrence.** – First appears in the middle part of the Piotrawin section in the *Imoceras* *inkermanensis* inoceramid Zone and ranges to the top of the analysed part of the succession.

*Bolivina incrassata* Reuss, 1851  
(Fig. 3K–M)

*Bolivina incrassata* n. sp. – Reuss, 1851: 45, pl. 4, fig. 13 (*fide* Ellis et Messina, Cat. of Foram.).
*Bolivina incrassata* Reuss – Hofker, 1966: 39, pl. 5, fig. 42, p. 59, pl. 10, figs. 90, 91.
*Bolivina incrassata* Reuss – Robaszynski et al., 1985, pl. 5, fig. 7.
*Coryphostoma incrassata* (Reuss) – Peryt, 2000, pl. 1, figs. 1, 2, 11, 12.

**Description.** – Test biserial, free, slightly compressed with entire outline and sub-rounded periphery. Aperture an elongated elliptical slit extending from basal suture to terminal position of the final chamber.

**Remarks.** – *Bolivina incrassata* differs from *B. decurrens* in lacking indented, acute and spinose margins.

**Occurrence.** – First appears in the Dorotka N section in the upper part of the *Bostrychoceras polyplum* ammonite Zone and ranges to the top of the studied succession.

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Genus *Bolivinoides* Cushman, 1927
*Bolivinoides miliaris* Hiltermann et Koch, 1950  
(Fig. 3P)

*Bolivinoides miliaris* (Marsson) *miliaris* Hiltermann and Koch – Pozarska, 1954: 254, fig. 4.
*Bolivinoides miliaris* Hiltermann and Koch – Hart et al., 1981: 182, pl. 7.5, fig. 3.
*Bolivinoides australis* Edgell – Robaszynski et al., 1985, pl. 6, fig. 5.

**Description.** – Test robust, kite-shaped in outline, compressed to an elongated oval shape in cross section, 5 to 6 ornamental lobes. Early part of the test ornamented by numerous short tubercles and nodules.

**Remarks.** – In the upper part of the *Sphaeroceramus pertenuiformis* inoceramid Zone appear forms which differ from *B. miliaris* in possessing two parallel median rows of tubercles. They are probably transitional forms from *B. miliaris* to *B. draco* (Fig. 3Q, R).
Occurrence. – First appears in the Doroinka N section in the upper part of the *Bostrychoceras polyplocum* ammonite Zone and ranges to the top of the studied succession.

Superfamily Chilostomellacea Brady, 1881
Family Globorotaliidae Loeblich and Tappan, 1964
Genus *Globorotalites* Brotnzen, 1942
*Globorotalites emdyensis* Vasilenko, 1961 (Fig. 4Aa–Ac, Ca–Cc)

*Globorotalites emdyensis* n.sp. – Vasilenko, April 1961: 60–61, pl. 10, figs. 3a, b, w, 4a, b, w.

*Globorotalites hittermanni* n. sp. – Kaever, September 1961: 418–419, pl. 20, fig. 1a–c.

*Globorotalites hittermanni* Kaever – Hart et al., 1981: 198, pl. 7.13, figs. 10, 11.


*Globorotalites hittermanni* Kaever – Peryt, 2000, pl. 2, figs. 7, 8, 10, 11.

*Globorotalites hittermanni* Kaever – Dubicka and Peryt, 2012a, fig. 4D12, E1E2.

Description. – Test trochospiral, planoconvex to biconvex, spiral side slightly to moderately convex; umbilical side convex, looks like a low cone with a wide base; periphery with poreless carina; 7 to 9 chambers enlarging gradually in the last whorl; sutures oblique, limbate and elevated on the spiral side; radial, curved and slightly depressed on the umbilical side; surface smooth; low and slitlike interiomarginal aperture with distinct mural reflectus on the umbilical side.

Remarks. – It differs from *G. michelinianus* in having a biconvex test and limbate, raised sutures on the spiral side. In 1961 Kaever and Vasilenko independently described two new species of *Globorotalites*: *Globorotalites hittermanni* from northern Germany and *G. emdyensis* from the Mangyshlak peninsula, Kazakhstan. Gawor-Biedowa (1992) already suggested that the two species were conspecific. However, because she did not see the original paper with the description of *G. hittermanni* she was unable to form a judgement regarding priority. After comparison of the original figures of the holotypes, the descriptions of the two species and their variability, in view of the fact that the two taxa have the same stratigraphical range we came to the conclusion that they represent one species. Because the paper by Vasilenko was published in April 1961 while the paper by Kaever was published in September 1961, the name *Globorotalites emdyensis* has priority.

Occurrence. – First appears in the Doroinka section in the *Cataceramus subcompressus* inoceramid Zone and in the *Bostrychoceras polyplocum* ammonite Zone and ranges to the upper part of the “*Inoceramus* inkemanensis” Zone.

*Globorotalites michelinianus* (d’Orbigny, 1840) (Fig. 4Da–Dc)

*Rotalina micheliniana* n. sp. – d’Orbigny, 1840: 31–32, pl. 3, figs. 1–3 (ide Ellis et Messina, Cat. of Foram.).

*Globorotalites michelinianus* (d’Orbigny) – Hart et al., 1981: 200, pl. 7.14, figs. 1, 2.


Description. – Test conical; spiral side flat to slightly concave, umbilical side strongly convex; 5–7 chambers in the last whorl; surface smooth; periphery with poreless carina; chambers on the umbilical side enlarging gradually in height; the last (highest) chamber forming the peak of the cone; sutures curved and slightly depressed on the spiral side, radial and flat, almost invisible on the umbilical side; pseudoumbilicus small and shallow; low and slitlike interiomarginal aperture on the umbilical side.

Occurrence. – Noted from the bottom of the studied succession up to the middle part of the *Didymoceras donezianum* ammonite Zone.

Family Osangulariidae Loeblich and Tappan, 1964
Genus *Osangularia* Brotnzen, 1940
*Osangularia navarroana* (Cushman, 1938) (Fig. 4Ba–Bb, F)

*Pulvinulinella navarroana* n. sp. – Cushman, 1938: 66, pl. 11, figs. 5a–c.

*Osangularia navarroana* (Cushman) – Hart et al., 1981: 212, pl. 7.20, figs. 7, 8.


*Osangularia navarroana* (Cushman) – Gawor-Biedowa, 1992: 152, pl. 33, figs. 1–3.

*Osangularia navarroana* (Cushman) – Peryt, 2000, pl. 2, figs. 1–3.

Description. – Test trochospiral, biconvex with more convex spiral and much less convex umbilical side; flush margin outline, periphery circular and sharply ended; test surface smooth; aperture areal, elongated slit located on the flat chamber surface on the involute side.

Occurrence. – First appears in the upper part of the Wola Pawlowska section in the *Sphaeroceras partenuiformis* inoceramid Zone and ranges to the top of the studied succession.

Family Gavelinellidae Hofker, 1956
Genus *Angulogavelinella* Hofker, 1957
*Angulogavelinella gracilis* (Marsson, 1878) (Fig. 4Ea–Ec)

*Discorbina gracilis* n. sp. – Marsson, 1878: 166, pl. 4, fig. 34 (ide Ellis et Messina, Cat. of Foram.).


*Angulogavelinella gracilis* (Marsson) – Peryt, 2000, pl. 2, figs. 4–6.

*Angulogavelinella gracilis* (Marsson) – Dubicka and Peryt, 2012a, fig. 4G, H1–2.
**Description.** – Test low trochospiral, biconvex, with almost flush margin outline. On the spiral smooth side the last whorl is depressed and the central part of the test is raised. On the umbilical and involute side of the test sutures are very strongly raised, broad, prominent and curved back to the periphery.

**Remarks.** – Early forms of *A. gracilis* occurring in the upper part of Łopoczno succession possess a flat spiral side of the test.

**Occurrence.** – First appears at the base of the Łopoczno section in the *Sphaeroceramus pertenuiformis* inoceramid Zone and ranges to the top of the studied succession. The species is very rare in the “Inoceramus” *inkermanensis* Zone.

**Genus Gavelinella** Broten, 1942

*Gavelinella clementiana* (d’Orbigny, 1840) (Fig. 4Ga–Gc)

*Rosalina clementiana* – d’Orbigny, 1840: 37, pl. 3, figs. 23–25 (fide Ellis et Messina, Cat. of Foram.).

*Stensioeina annae* n. sp. – Pożaryska, 1954: 265–267, figs. 24, 25.


*Stensioeina annae* Pożaryska – Bieda, 1958: 52, fig. 20a–c.

*Gavelinella clementiana* (d’Orbigny) – Hart et al., 1981: 194, pl. 7.11, figs. 1–3.

*Stensioeina clementiana* (d’Orbigny) – Robaszynski et al., 1985, pl. 4, fig. 2.


**Description.** – Test low trochospiral, with flat or slightly depressed spiral side and convex umbilical side, margin bluntly rounded. Characteristic ornamentation (numerous ridges and tubercles) occurs on both sides of the test or only on umbilical side.

**Occurrence.** – Noted in the Dorotka section in the *Cataceramus subcompressus* inoceramid Zone. It is widely known in distinctly older strata, at least from the lower Campanian.

*Gavelinella monterelensis* (Marie, 1941) (Fig. 4Ha–Hc)

**Description.** – Test very low trochospiral, almost planispiral, biconvex with almost flush margin outline. Periphery circular with imperforate “keel-like” structure. Test biurnished with umbilical boss more distinct and raised than spiral side boss; numerous chambers (from 12 to 14 in the final whorl).

**Occurrence.** – Noted from the bottom of the studied succession up to basal part of the “Inoceramus” *altus* inoceramid Zone.

**Planktonic foraminifera of the Upper Campanian–Lower Maastrichtian of the Middle Vistula River section (comprising eight inoceramid bivalve zones of Walaszczyk, 2004), are represented by cosmopolitan taxa, with rather moderate chemostratigraphic potential.** Planktonic foraminifera taxa that are important biostratigraphical markers elsewhere, particularly in the Tethyan Realm, do not occur, and thus direct correlation with the standard planktonic foraminiferal zonation and distant regions are impossible/difficult. However, we were able to recognize one significant planktonic foraminiferal bioevent, i.e. the FO’s of *Rugoglobigerina milamensis, R. hexacamerata* and *R. pennyi*, dated to the uppermost “I.” *redbirdensis* inoceramid Zone. This level, as defined by inoceramids (Walaszczyk, 2004), is very close to the Campanian/Maastrichtian boundary. This event may be a good proxy for this stage boundary in temperate regions.

Benthic foraminifera in the studied succession are generally abundant and well-preserved. In the course of this investigation we identified the following twelve benthic foraminiferal bioevents in ascending stratigraphical order:

- FO of *Gavelinella clementiana*
- LO of *Gavelinella clementiana*
- LO of *Globorotalites michelinianus*
- LO of *Globorotalites emdyensis (= G. hiltermanni)*
- FO of *Bolivina incrassata*
- FO of *Bolivinoides miliaris*
- FO of *Neoflabellina praereticulata*
- FO of *Angulogavelinella gracilis (= A. bettenstaedti)*
- LO of *Gavelinella monterelensis*
- FO of *Osangularia navaroana*
- FO of *Bolivina decurrens*
- FO of *Neoflabellina reticulata*

Apart from the LO of *G. clementiana* and FO of *N. praereticulata*, which seem to be more diachronous, all of the other events are located in very similar stratigraphical positions in the Middle Vistula River section, in northern Germany (Lägerdorf-Kronmoor), eastern England and in some eastern European sections. Accordingly they can serve as important markers for stratigraphical correlations across Europe.

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Foraminiferal bioevents in the Upper Campanian to lowest Maastrichtian of the Middle Vistula River section, Poland


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