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VERSITA

Faunal dynamics of foraminiferal assemblages in the Bathonian (Middle Jurassic) ore-bearing clays at Gnaszyn, Kraków-Silesia Homocline, Poland

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ABSTRACT:

Smoleń, J. 2012. Faunal dynamics of foraminiferal assemblages in the Bathonian (Middle Jurassic) ore-bearing clays at Gnaszyn, Kraków-Silesia Homocline, Poland. *Acta Geologica Polonica*, **62** (3), 403–419. Warszawa.

The faunal dynamics of benthic foraminifera in the Middle Jurassic ore-bearing clays of Gnaszyn (Kraków-Częstochowa Upland, south-central Poland) are used to reconstruct sedimentary environments. Two types of foraminiferal assemblages, distinct in their quantitative and qualitative composition, were distinguished; type I assemblages, characterizing intervals between horizons with sideritic concretions; and type II assemblages, characterising horizons with sideritic concretions. Benthic foraminifers were further subdivided into eight ecological morphogroups, based on their morphological features and micro-habitats. Type I assemblages consist mostly of plano/concavo-convex, small-sized epifaunal morphotypes, with a restricted occurrence of shallow infaunal forms and a scarcity of deep infaunal taxa, which suggests low-oxygen conditions in both sediment and bottom waters, and a high sedimentation rate in an outer shelf environment. Type II assemblages are characterized by high taxonomic diversity, high specimen abundance and variability of epifaunal and infaunal morphotypes representing a mixed group of specialized feeding strategies. This suggests optimum living conditions controlled by a lower sedimentation rate, relatively well-oxygenated bottom waters and sufficient or high food supply.

Key words: Foraminifera; Morphogroups; Palaeoecology; Oxygenation; Jurassic; Kraków-Silesia Homocline.

INTRODUCTION

The present study analyses the environmental conditions of the Middle Jurassic ore-bearing clays from Gnaszyn, Central Poland, based on their foraminiferal record. The analysis is a part of a multidisciplinary project aimed at reconstruction of the sedimentary conditions of the Gnaszyn succession (see Gedl and Kaim 2012, this issue). The project is based on several fossil groups, as well as on sedimentological and geochemical data. Each study in the project is based on the same sample set, spanning the Middle–Upper Bathonian succession exposed in an active clay-pit in Gnaszyn. Preliminary studies on the succession (Smoleń in Gedl *et al.* 2003; Smoleń 2004, 2006), showed that the foraminiferal assemblages show distinct fluctuations in their taxonomic composition, apparently reflecting environmental changes during the deposition of the ore-bearing clays.

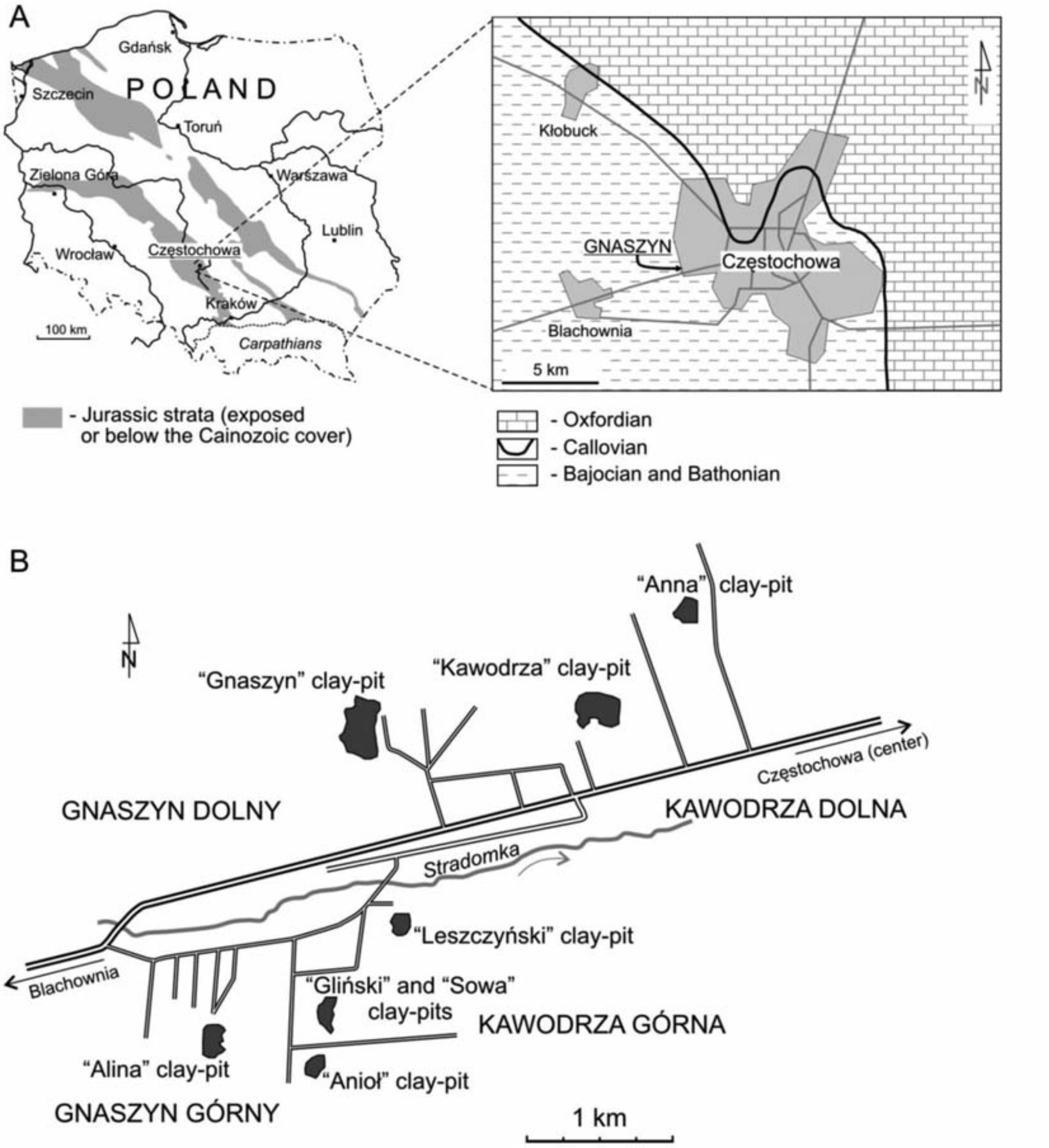
Although some palaeoecological remarks based on foraminifers from the Middle Jurassic ore-bearing clays in southern Poland were published (Garbowska *et al.* 1978), most of the older publications are focused on their taxonomy and biostratigraphic significance (e. g., Pazdro 1954, 1959, 1969; Kopik 1988).

MATERIAL AND METHODS

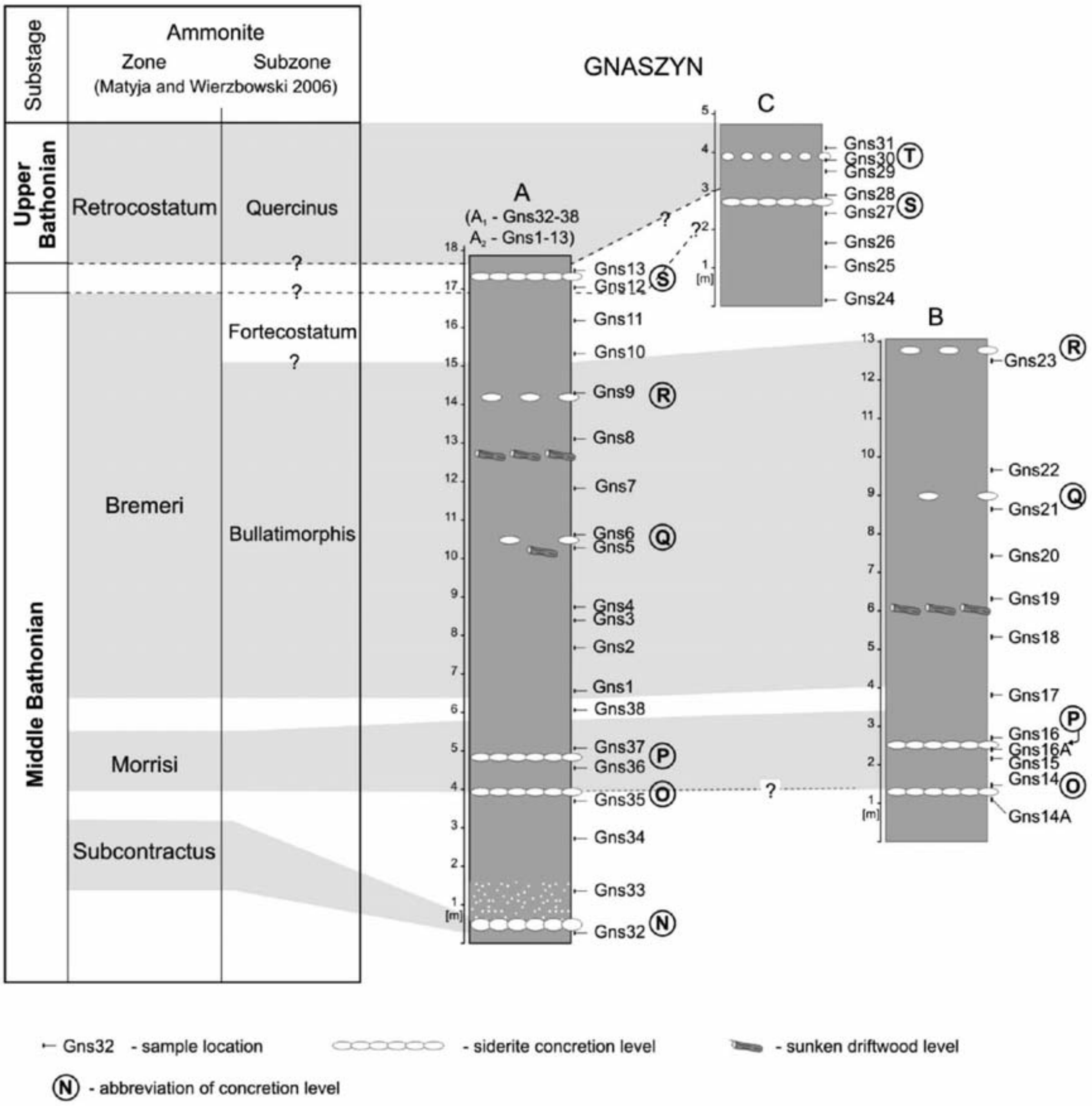
The Middle Jurassic ore-bearing clays in Gnaszyn, SW of Częstochowa (Kraków-Silesia Homocline, south-central Poland; Text-fig. 1), form a 23-m thick succession of monotonous, dark greyish mudstones and claystones, with 7 horizons of sideritic concretions (Text-fig. 2). The sediments are strongly bioturbated, with the original sedimentary structures only rarely preserved (for more details see Leonowicz 2012, this issue; Gedl and Kaim 2012, this issue). The succession is of Middle–Late Bathonian age (Subcontractus through Retrocostatum ammonite zones; Matyja and Wierzbowski 2003).

The set of 38 samples was collected from three sections within the Gnaszyn clay-pit (see Gedl and Kaim 2012 for more details on sample location). Samples from the north-eastern quarry wall (section A; samples Gns32–38 and Gns1–13; Text-fig. 2A) document the lower and middle part of the succession; samples from southern part of the quarry (section C; Gns24–31; Text-fig. 2C), document the uppermost part of the succession, and samples from the north-western wall (Section B; Gns14A–22; Text-fig. 2B), duplicate the middle part of the succession.

All samples were subjected to a standard maceration technique. Rock samples were disintegrated with Glauber's salt, washed with water and sieved through a 0.1 mm sieve. A minimum of 300 specimens was picked from each residue for statistical analysis except for sam-



Text-fig. 1. Geological sketch-map of the Częstochowa area (A – after Majewski 2000) and location of the studied Gnaszyn clay-pit (B – after Matyja and Wierzbowski 2003)



Text-fig. 2. Lithological logs of the Gnaszyn sections with sample location (from Gedl and Kaim 2012)

ples Gns29–33 (section C, Text-fig. 1), where fewer than 100 specimens were picked. Taxonomic observations and photographs were taken under a Nikon stereoscopic microscope SMZ-2T and SEM (LEO 1430), at the Polish Geological Institute, Warszawa, Poland. The classification of Loeblich and Tappan (1987) is followed.

RESULTS

Foraminiferal assemblages

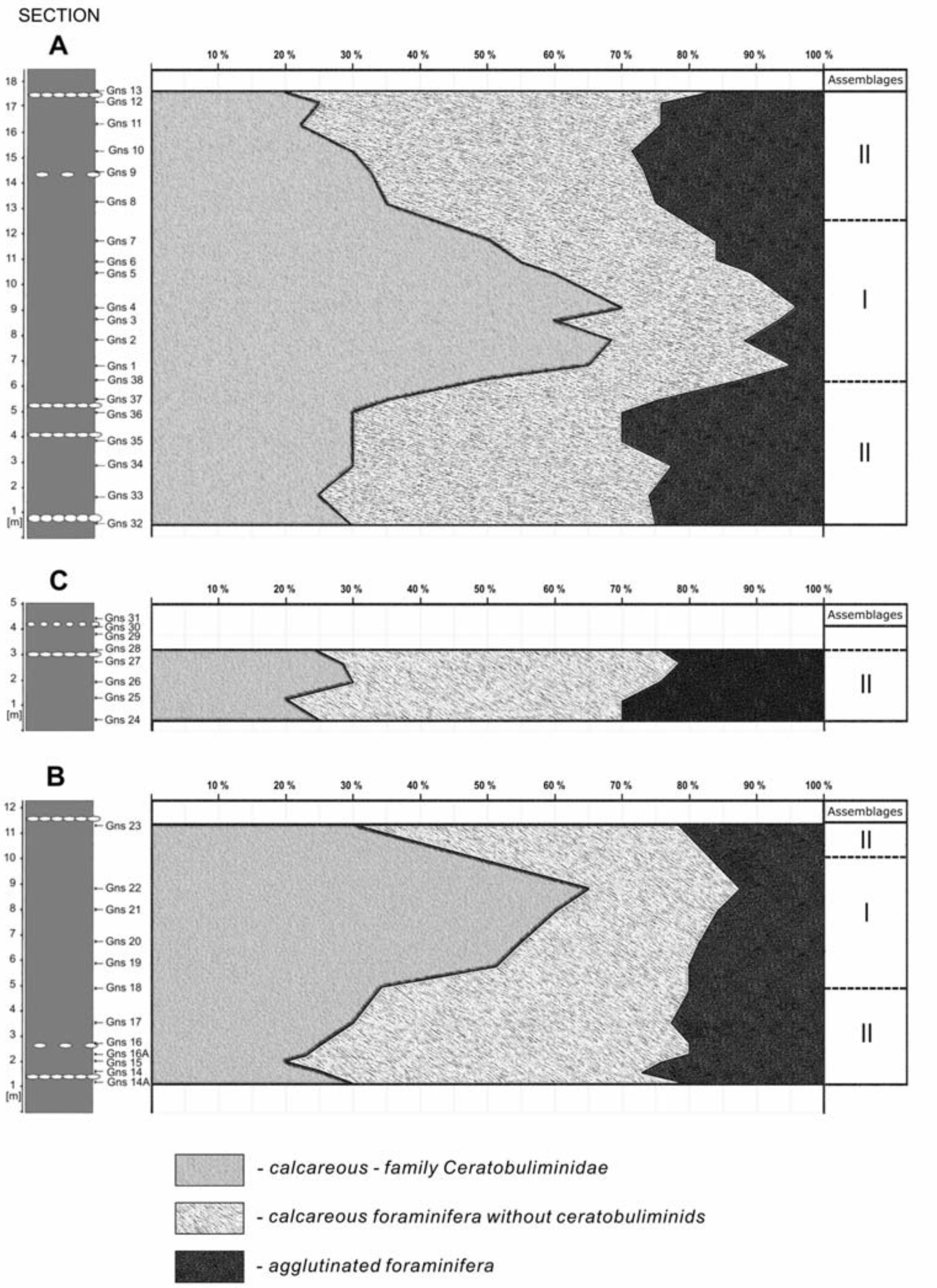
The Gnaszyn succession yielded 56 foraminiferal species (see Appendix). The assemblage is strongly dominated by calcareous benthic taxa. The agglutinated species are much less frequent and less diverse, and a single planktonic species, *Globuligerina bathoniana* (Text-fig. 7K), is known from only three samples (Gns4, Gns35, Gns14A). Two types of foraminiferal assemblages, distinct in their quantitative and qualitative composition (Text-fig 3), are distinguished; type I assemblages, characterizing the intervals between the horizons with sideritic concretions; and type II assemblages, characterising the horizons with sideritic concretions.

Type I assemblages. These assemblages occur in the middle of section A (samples Gns1–7) and in the middle of section B (samples Gns18–22). They are characterized by a low-diversity association of calcareous benthic foraminifera, which represent between 80% and 96% of

Foraminiferal assemblages **Species**	**assemblages type I** section A/ 1-7 section B/ 18-22	**assemblages type II** section A/ 32-38, 8-13 section B/ 14A-16, 23 section C/ 24-28
Ammobaculites fontinensis (Terquem)		•
Ammobaculites sp.	•	—
Ammodiscus cf. *glumaceus* Gerke & Sossipatrova	•	—
Ammodiscus sp.	•	—
Astacolus matutinus (d'Orbigny)	•	
Astacolus franconicus (Gümbel)		•
Astacolus suprajurassicus (Schwager)		—
Citharina cf. *oolithica* (Schwager)		•
Citharina sp.	•	•
Dentalina sp.		—
Epistomina cosifera Terquem		•
Epistomina nuda Terquem	▬	▭
Epistomina pentarima Dain	—	
Epistomina regularis Terquem		—
Frondicularia sp.		•
Garantella aff. *stellata* Kaptarenko		•
Geinitzinita nodosaria (Terquem)	•	•
Glomospira gordialis (Jones & Parker)		—
Globuligerina bathoniana (Pazdro)	•	•
Haplophragmoides sp.	—	—
Ichtyolaria cf. *nympha* Kopik	•	•
Ichtyolaria sp.	•	•
Lagena globosa (Montagu)	•	•
Lenticulina (*Astacolus*) *argonauta* (Kopik)		•
Lenticulina (*Astacolus*) *dictyotes dictyotes* (Deecke)		•
Lenticulina helios (Terquem)	—	—
Lenticulina kujaviana Kopik	—	
Lenticulina mamillaris (Terquem)	•	—
Lenticulina muensteri (Roemer)		—
Lenticulina quenstedti (Gümbel)		—
Lenticulina cf. *ruesti* (Wiśniowski)		•
Lenticulina volubilis Dain	—	—
Nodosaria dispar Franke		•
Nodosaria plicatilis Wiśniowski		—
Nodosaria pulchra (Franke)	—	•
Ophthalmidium carinatum agglutinans Pazdro	—	▭
Ophthalmidium carinatum terquemi Pazdro	•	▭
Paalzowella pazdroe Bielecka & Styk	•	•
Paleomiliolina czestochowiensis (Pazdro)	•	—
Paleomiliolina rawiensis (Pazdro)		•
Palmula deslongchampsi (Terquem)		•
Planularia eugenii (Terquem)	—	—
Planularia prava (Terquem)		•
Recurvoides sp.		—
Reinholdella crebra Pazdro	•	•
Reophax fusiformis (Willamson)	—	•
Reophax sterkii Hausler		—
Reophax sp.	•	—
Saracenaria oxfordiana Tappan		•
Saracenaria tricostata (Mitjanina)	•	—
Spirillina radiata Terquem	•	•
Spirillina sp.		•
Trochammina sp.		•
Trochamminoides sp		—
Trocholina conica Schlumberger		•
Vinelloidea infraoolithica (Terquem)		•
Number of species	28	42

• 1-10 — 11-30 ▭ 30-90 ▬ > 90 specimens

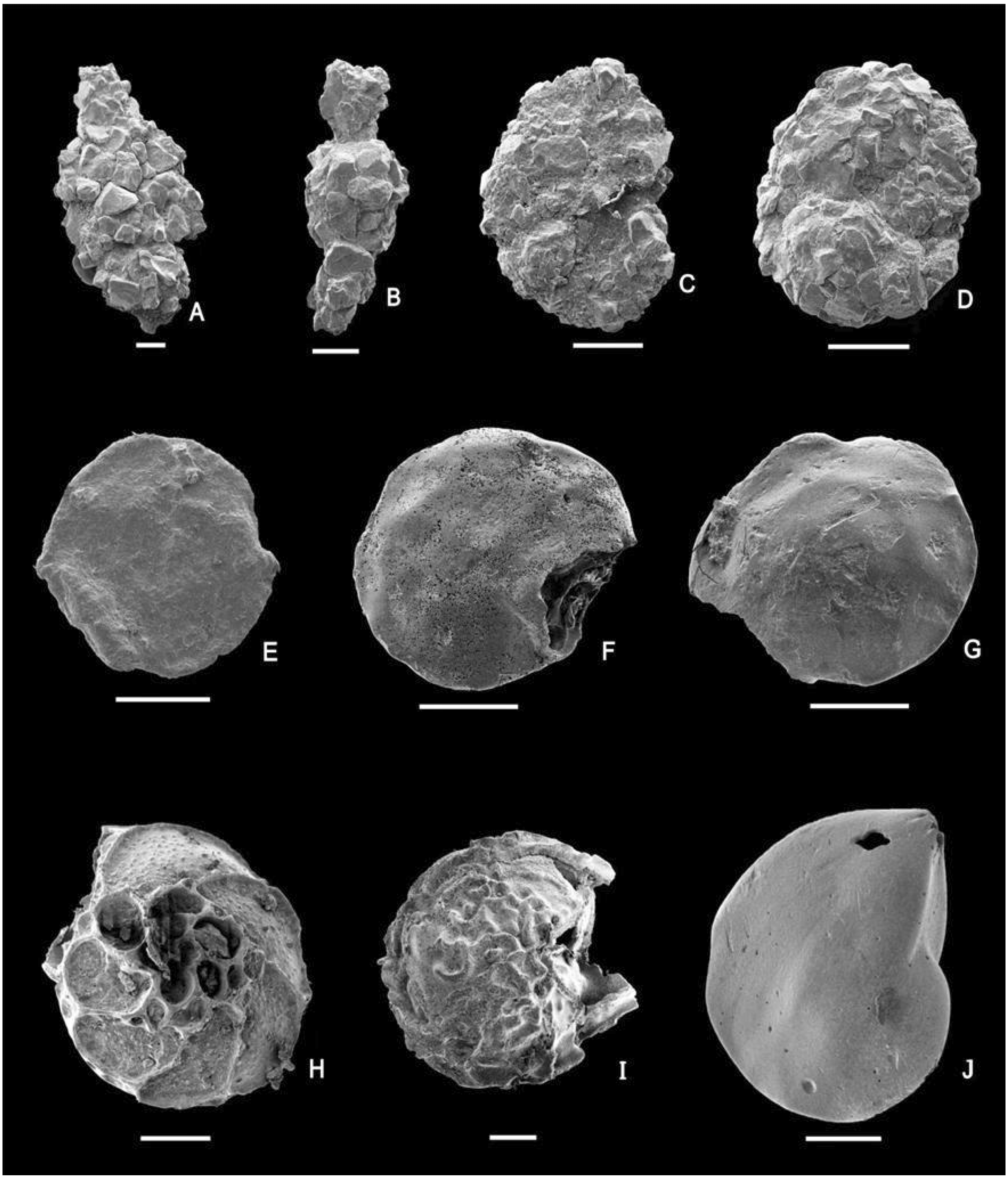
Text-fig. 3. Occurrence and frequency of the foraminifers in type I and II foraminiferal assemblages (I and II) in the Gnaszyn sections A, B and C the assemblage (Text-fig. 4). A characteristic feature of type I assemblages is the mass occurrence of the genus *Epistomina* (family Ceratobuliminidae), and especially of its species *Epistomina nuda* (Text-fig. 5F, G), represented by small-sized (100–200 µm) tests. In some samples this species constitutes up to 70% of the whole assemblage (Text-fig. 4). Other calcareous forms include: infrequent miliolids, *Ophthalmidium carinatum agglutinans* (Text-fig. 7 D, E), *O. carinatum terquemi*, and *Paleomiliolina czestochowiensis*; and infrequent nodosariids, *Nodosaria pulchra* and *Geinitzinita nodosaria*. The family Vaginulinidae is represented by *Lenticulina helios*, *L. mamillaris*, *L. kujaviana*, *L. volubilis*, *Saracenaria tricostata*, *Planularia eugenii*, and representatives of *Astacolus*, *Citharina* and *Ichtyolaria*. Additionally, *Spirillina radiata*, *Paalzowella pazdroe*, *Epistomina pentarima*, *Reinholdella crebra* and *Lagena globosa* (Text-fig. 7H) occur occasionally.



Text-fig. 4. Relative abundance (%) of calcareous and agglutinated foraminifers and distinguished type of foraminiferal assemblages (I and II) in the Gnaszyn sections A, B and C

Agglutinated foraminifera constitute roughly 20% of the assemblages (Text-fig. 4), and are represented by *Ammodiscus* cf. *glumaceus* (Text-fig. 5E), *Ammodiscus* sp., *Reophax fusiformis*, *Reophax* sp. (Text-fig. 5A), *Haplophragmoides* sp (Text-fig. 5D) and *Ammobaculites* sp.

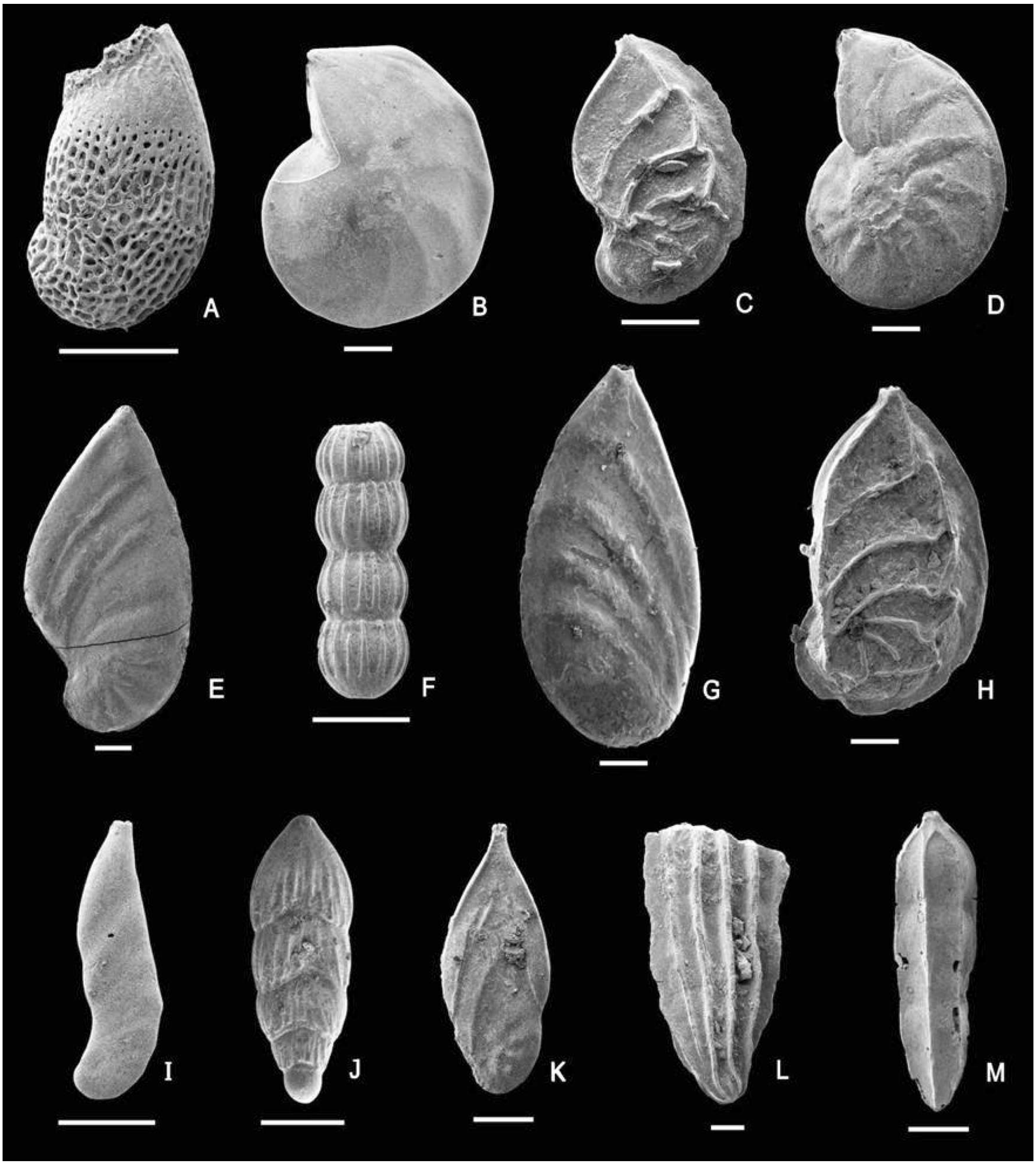
Type II assemblages are present in the lowermost and upper part of section A (samples Gns32–38 and Gns8–13 respectively), in the lower part (samples Gns14A–16) and topmost part of section B (sample Gns23), and in the lower part of section C (samples Gns24–28).



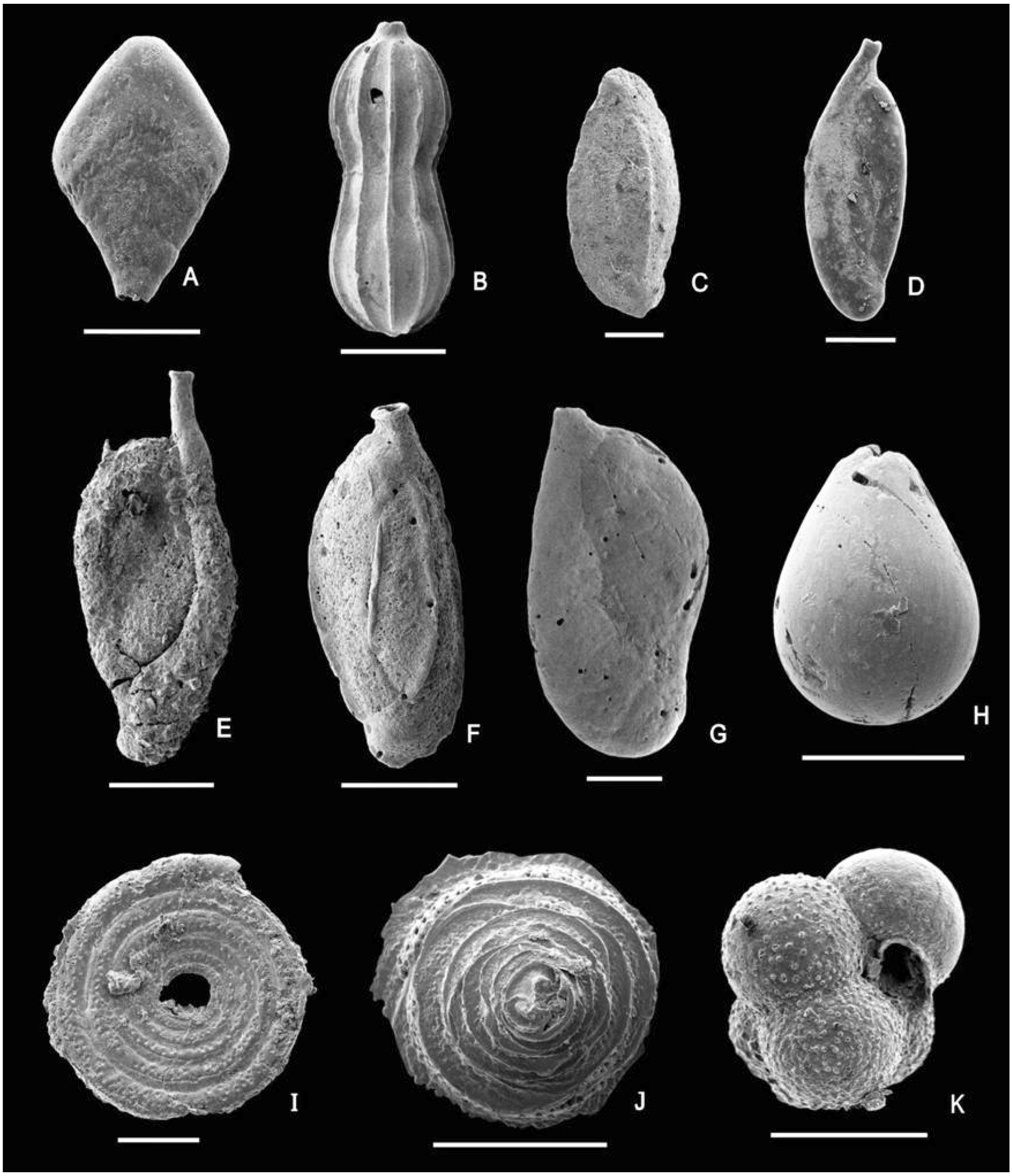
Text-fig. 5. Foraminifera from the Gnaszyn ore-bearing clays: representatives of ag1, ag2, ag3, c1 and c2 morphogroups (SEM microphotographs; scale bar – 100 µm): A, B – ag2 morphogroup: A – *Reophax fusiformis* (Willamson), B – *Reophax sterkii* Hausler; C, D – ag1 morphogroup: C – *Ammobaculites fontinensis* (Terquem), D – *Haplophragmoides* sp.; E – ag3 morphogroup: *Ammodiscus* cf. *glumaceus* Gerke and Sossipatrova; F-I – c1 morphogroup: F-G – E*pistomina nuda* Terquem, H, I – *Epistomina regularis* Terquem; J – c2 morphogroup: *Lenticulina mamillaris* (Terquem)

Type II assemblages are characterised by higher taxonomic richness than type I assemblages (Text-fig. 3). The most diverse and numerous specimens within type II assemblages have been observed in horizons with siderite concretions (samples Gns35–37, Gns14A–16, Gns12–13, Gns23 and Gns28).

Similarly as type I assemblages, type II assemblages are dominated by benthic calcareous species, which comprise between 70% and 80% of the assemblage (Text-fig. 4). The most frequent are species of the family Ceratobuliminidae (about 30%) which show higher taxonomic diversity than in type I assemblages. Cerato-



Text-fig. 6. Foraminifera from the Gnaszyn ore-bearing clays: representatives of c2 and c3 morphogroups (SEM microphotographs; scale bar – 100 µm): A-E, G-I – c2 morphogroup: A – *Lenticulina* (*Astacolus*) *dictyotes dictyotes* (Deecke), B – *Lenticulina munsterii* (Roemer), C – *Lenticulina* (*Astacolus*) argonauta (Kopik), D – *Lenticulina helios* (Terquem), E – *Planularia prava* (Terquem), G – *Planularia eugenii* (Terquem), H – *Saracenaria tricostata* (Mitjanina), I – *Astacolus matutinus* (d'Orbigny); F, J-M – c3 morphogroup: F – *Nodosaria pulchra* (Franke), J – *Geinitzinita nodosaria* (Terquem), K – *Palmula deslongchampsi* (Terquem), L – *Citharina* cf. *oolithica* (Schwager), M – *Nodosaria dispar* Franke buliminidae consist not only of smooth forms, such as *Epistomina nuda*, but also of species with ornamented tests, such as *Epistomina regularis* [Text-fig. 5H, I], *Epistomina costifera*, and *Garantella* aff. *stellata*. Also frequent is the family Vaginulinidae, represented by the genus *Lenticulina* (i.e., *L. muensteri* [Text-fig. 6B], *L. mamillaris* [Text-fig. 5J], *L.* (*Astacolus*) *dictyotes dictyotes* [Text-fig. 6A], *L. helios* [Text-fig. 6D], *L.* (*Astacolus*) *argonauta* [Text-fig. 6C], *L.* cf. *ruesti*, and *L. quenstedti*). The other Vaginulinidae species include:

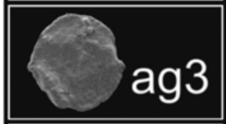
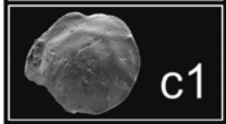


Text-fig. 7. Foraminifera from the Gnaszyn ore-bearing clays: representatives of the c3, c4 and c5 morphogroups, and planktonic foraminifera (SEM microphotographs; scale bar – 100 µm): A, B – c3 morphogroup: A – *Ichtyolaria* sp., B – *Nodosaria plicatilis* Wiśniowski; C-G – c4 morphogroup: C – *Paleomiliolina rawiensis* (Pazdro), D, E – *Ophthalmidium carinatum agglutinans* Pazdro, F – *Paleomiliolina czestochowiensis* (Pazdro), G – *Ophthalmidium carinatum terquemi* Pazdro; H-J – c5 morphogroup: H – *Lagena globosa* (Montagu), I – *Spirillina radiata* Terquem, J – *Paalzowella pazdroe* Bielecka and Styk; K – planktonic formaminifera: *Globuligerina bathoniana* (Pazdro)

Astacolus matutinus (Text-fig. 6I), *A. franconicus*, *A. suprajurassicus*, *Saracenaria oxfordiana*, *S. tricostata* (Text-fig. 6H), *Citharina* cf. *oolithica* (Text-fig. 6L), *Citharina* sp., *Planularia eugenii* (Text-fig. 6G), *P. prava* (Text-fig. 6E) and *Palmula deslongchampsi* (Text-fig. 6K). Type II assemblages are also characterised by a higher frequency and higher diversity of miliolids: *Ophthalmidium carinatum agglutinans*, *O. carinatum terguemi* (Text-fig. 7G), *Paleomiliolina czestochowiensis* (Text-fig. 7F) and *Paleomiliolina rawiensis* (Text-fig. 7C), and the family Nodosariidae: *Nodosaria pulchra* (Text-fig. 6F), *N. dispar* (Text-fig. 6M), *N. plicatilis* (Text-fig. 7B), *Geinitzinita nodosaria* (Text-fig. 6J) and *Dentalina* sp. Additional calcareous species found in type II assemblages include *Ichtyolaria* cf. *nympha*, *Ichtyolaria* sp. (Text-fig.7A), *Spirillina radiata* (Text-fig. 7I), *Paalzowella pazdroe* (Text-fig. 7J), *Lagena globosa*, *Trocholina conica* and the incrusting species *Vinelloidea infraoolithica*. Exclusively in type II assemblages occur: *Glomospira gordialis*, *Ammobaculites fontinensis* (Text-fig. 5C), *Reophax sterkii* (Text-fig. 5B), and species of the genera *Ammodiscus*, *Haplophragmoides*, *Trochamminoides*, *Recurvoides*, *Ammobaculites* and *Trochammina*. When compared with type I assemblages, type II assemblages contain more agglutinated foraminifers, reaching up to 30% of the assemblage (Text-fig. 4).

Benthic foraminiferal morphogroups

Based on test shape and chamber arrangement, as well as on microhabits (feeding strategy and/or living position), eight morphogroups within the benthic foraminifers have been distinguished; 3 in agglutinated

Morphogroups (Nagy, 1992 Koutsoukos et al., 1990)	**Morphotypes Test shape**	**Life position**	**Feeding strategy**	**Genus (this paper)**
 ag1	planoconvex trochospiral multilocular	semiinaunal epifaunal	active detritivorous omnivorous	*Haplophragmoides* *Trochamminoides* *Recurvoides* *Trochammina*
 ag2	subcylindrical tapered multilocular	infaunal	deposit feeders detritivorous bacterial scavengers	*Reophax* *Ammobaculites*
 ag3	flatted planispiral trochospiral	epifaunal	omnivorous detritivorous herbivorous	*Glomospira* *Ammodiscus*
 c1	plano/ concavo-convex, trochospiral with a convex spiral side, multilocular	epifaunal	deposits feeders detritivorous omnivorous	*Epistomina* *Reinholdella* *Garantella*
 c2	lenticuluar, biconvex planispirally coiled multilocular	epifaunal, shallow infaunal	active deposit feeders detritivorous herbivorous	*Lenticulina* *Astacolus* *Planularia* *Saracenaria*
 c3	elongate, straight to arcuate, multilocular	epifaunal, shadow infaunal	deposi feeders herbivorous, omnivorous, bacterial detrival scavengers	*Dentalia, Nodosaria* *Geinitzinita, Citharina* *Ichtyolaria, Palmula* *Frondicularia*
 c4	fusiform in outline, truncate, multilocular	epifaunal	active deposit feeders detritivorous herbivorous	*Ophthalmidium* *Paleomiliolina*
 c5	globular to ovate discoidal to conical	epifaunal	active deposit feeders herbivorous omnivorous, bacterial detrival scavengers	*Spirillina, Lagena* *Trocholina* *Paalzowella* *Vinelloidea*

Text-fig. 8. Morphogroups of benthic foraminifers distinguished in the Middle-Upper Bathonian deposits of the Gnaszyn succession (ag1–ag3; Text-fig. 8) and 5 in calcareous foraminifera (c1–c5; Text-fig. 8). [For a species list of a particular morphogroup see Appendix II.] The grouping is based on models proposed earlier for agglutinated (Jones and Charnock 1985; Nagy 1992; Tyszka 1994; Kuhnt *et al.* 1996; Nagy *et al.* 2009; Reolid *et al.* 2010) and calcareous assemblages (Bernhard 1986; Koutsoukos *et al*. 1990; Szydło 2004; Reolid *et al.* 2008, 2008a).

Morphogroups of agglutinated foraminifers

Morphogroup ag1: Composed of multilocular, planoconvex, planispirally or trochospirally coiled morphotypes of the genera *Haplophragmoides*, *Recurvoides*, *Trochamminoides* and *Trochammina*. Recent forms of this morphotypes are active omnivorous epifaunal taxa attached to algae and sea-grasses, or deposit feeding semi-infaunal taxa grazing on the sediment interface (Jones and Charnock 1985). They dominate horizons with sideritic concretions (type II assemblages); only a few specimens have been found in type I assemblages, characterising the intervening intervals.

Morphogroup ag2: Consists of multilocular foraminifera with subcylindrical or tapered morphotypes. The majority of species belong to infaunal deposit feeders, detritivorous and microbial scavengers (Jones and Charnock 1985; Kaminski *et al*. 1988; Nagy 1992; Reolid *et al.* 2008). In the studied succession this morphogroup includes representatives of the genera *Reophax* and *Ammobaculites*, which are the most frequent in type II assemblages, and hardly present in type I assemblages.

Morphogroup ag3: Composed of one morphotype with usually flattened, planispirally coiled tests (also irregular in shape), of the genera *Glomospira* and *Ammodiscus*. Extant foraminifera of this morphotype represent omnivorous epifaunal taxa living attached to algae and seagrasses, or living directly on the sea bottom (Jones and Charnock 1985). Representatives of this morphogroup are rather uncommon in the studied deposits; however their number is higher in the horizons with sideritic concretions.

Morphogroups of calcareous foraminifera

Morphogroup c1: Composed of multilocular, plano/concavo-convex trochospirally coiled morphotypes with a convex spiral side. In the material studied, morphogroup c1 is represented by *Epistomina*, *Reinholdella* and *Garantella*. Extant counterparts inhabit shelf environments where they live at the sediment surface as deposit feeders, detritivorous or omnivorous epifaunal taxa. In the studied succession a mass occurrence of *Epistomina nuda* is observed in type I assemblages. A high frequency of smooth-shelled small-sized taxa is reported from environments with depleted oxygen content (Bernhard 1986; Koutsoukos *et al.* 1990; Tyszka 1994). Morphogroup c1 of type II assemblages is characterised by a higher taxonomic diversity, including both smooth and ornamented taxa of the genera *Epistomina* and *Garantella*.

Morphogroup c2: Composed of forms lenticular in shape, with multilocular, biconvex, planispirally coiled, smooth or weakly ornamented tests. The genera *Lenticulina*, *Astacolus*, *Planularia* and *Saracenaria* belong here. Included taxa are epifaunal or shallow infaunal active deposit feeders having both a herbivorous and detritivorous diet. They prefer well ventilated shelf environments with a high oxygen content in the bottom waters (Bernhard 1986; Koutsoukos *et al*. 1990). Jurassic *Lenticulina* had a higher ecological tolerance and opportunistic behaviour than extant forms (Rey *et al.* 1994; Tyszka 1994; Reolid *et al*. 2008). Morphogroup c2 is infrequent in type I assemblages and is quite frequent in type II assemblages.

Morphogroup c3: Represented by elongate, straight to arcuate morphotypes, with multilocular smooth or ornamented tests, of the genera *Dentalina*, *Nodosaria*, *Geinitzinita*, *Ichtyolaria*, *Palmula, Frondicularia* and *Citharina*. These are epifaunal or shallow infaunal deposits feeders (omnivorous, herbivorous, and microbial scavengers) preferring well oxygenated environments (Koutsoukos *et al*. 1990). Some morphotypes (e.g., *Planularia* and *Frondicularia*) tolerate environments with reduced oxygen (Bernhard 1986). Morphogroup c3 occurs most frequently in type II assemblages.

Morphogroup c4: Composed of benthic calcareous foraminifera with porcellaneous tests. These are multilocular taxa with an elongate test of fusiform and truncate outline, represented by miliolids belonging to the genera *Ophthalmidium* and *Paleomiliolina*. Recent foraminifera with similar morphology are epifaunal, active deposit feeders (both detritivorous and herbivorous). They prefer shallow, well ventilated and oxygenated shelf environments (Koutsoukos *et al*. 1990). Morphogroup c4 is frequent in type II assemblages, rare in type I assemblages.

Morphogroup c5: Composed of diverse morphotypes of discoidal and globular to ovate, as well as conical shells. Their representatives, *Lagena*, *Spirillina*, *Tro-*

cholina and *Paalzowella*, are active deposit feeders (herbivorous, omnivorous, and microbial scavengers), epifaunal, or shallow inflaunal, vagile or sessile (Kitazato 1988). Some are shallow omnivorous infauna living at the water-sediment interface (Koutsoukos *et al*. 1990). They prefer well oxygenated environments, although can tolerate depleted oxygen content (Szydło 2005; Reolid *et al*. 2008a). In the studied material morphogroup c5 is rare; more common in type II assemblages, in which an incrusting species, *Vinelloidea infraoolithica*, has been found.

DISCUSSION: PALEOENVIRONMENTAL IMPLICATIONS

The geochemical data from the Gnaszyn succession (Szczepanik *et al.* 2007; Zatoń *et al*. 2009) do not show significant variations, suggesting stable redox conditions during the Middle–Late Bathonian (Subcontractus through Retrocostatum zones) in the area. According to Szczepanik (Szczepanik *et al*. 2007) the succession was deposited in a normal marine environment under relatively well oxygenated (oxic to suboxic) bottom water conditions.

In contrast, foraminiferal assemblages in the succession show significant changes in their morphogroup composition (Text-fig. 9). These changes are recorded by fluctuating frequencies of particular morphotypes, which apparently reflect fluctuating palaeoenvironmental conditions during sedimentation of the Gnaszyn succession. The microfossil assemblages were thus much more sensitive to even subtle environmental changes than the geochemical record of the sediment. This agrees well with numerous reports emphasizing that benthic foraminifera are very good indicators of the nature of the sea bottom (e.g., Rey *et al.* 1994; Tyszka 1994; Nagy *et al*. 1995; Fugagnoli 2004; Reolid *et al*. 2010).

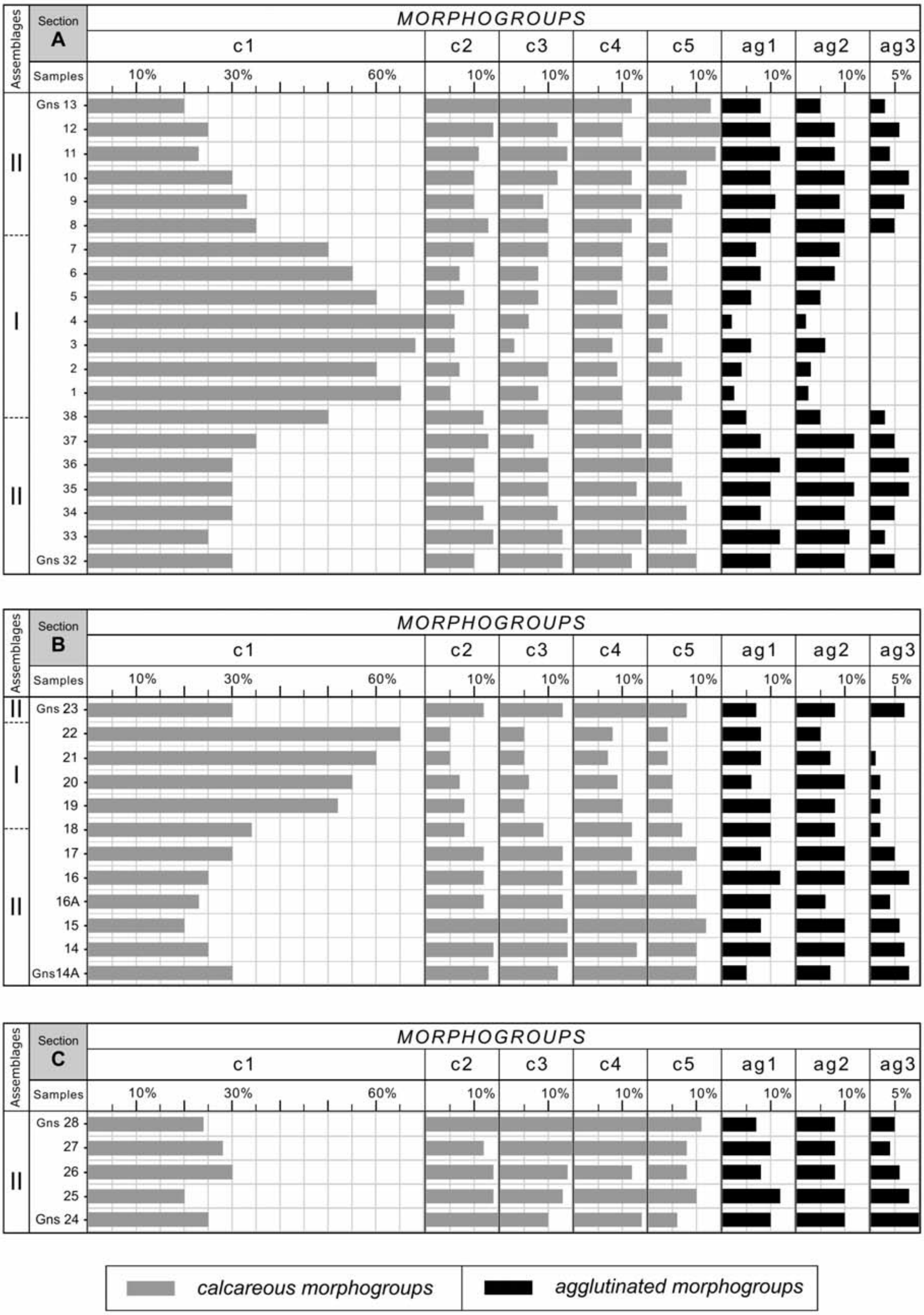
Type I assemblages, as defined herein, typical of deposits devoid of horizons with sideritic concretions, contain foraminifera dominated by epifaunal and shallow infaunal, mainly calcareous morphotypes (about 80% of the specimens in the assemblages) (Text-fig. 10A). The calcareous epifauna consist mainly of active, omnivorous deposit feeders of the family Ceratobuliminidae, represented chiefly by *Epistomina nuda*, a small-sized (up to 250 µm), non-ornamented, perforated, thin-walled form. This species belongs to morphogroup c1, comprising mostly opportunistic taxa, inhabiting oxygen-depleted, outer shelf environments (Bernhard 1986; Koutsoukos *et al*. 1990). Sagasti and Ballent (2002) described a monotypic assemblage of *Epistomina* associated with eutrophication of surface waters and development of low-oxygen conditions on the sea-floor. According to those authors, a bi/plano-convex trochospiral test, an epifaunal/semi-epifaunal microhabitat, and a deposit-feeding trophic strategy are favourable features for adaptation to oxygen-depressed sea-bottom conditions.

Studies on Recent foraminifers inhabiting oxygen-restricted environments demonstrate that such forms are frequently of small size because of their rapid reproduction in stress conditions (Phleger and Soutar 1973; Van der Zwaan and Jorissen 1991; Fugagnoli 2004), and may reflect difficulty in secreting carbon carbonate in hypoxic conditions (Bernhard 1986; Kaiho 1994).

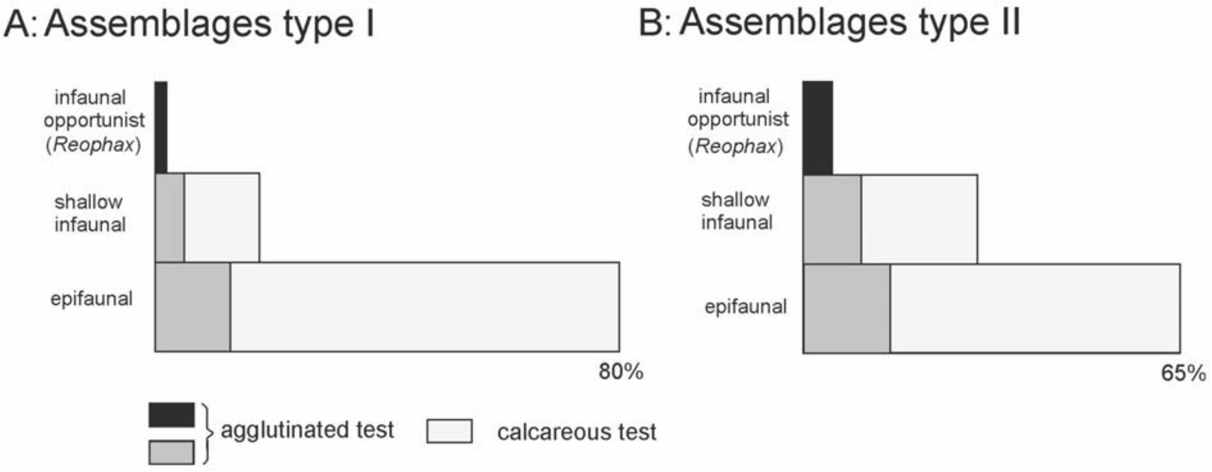
The remaining calcareous morphogroups distinguished within type I assemblages are rather uncommon. These are mainly epifaunal or shallow infaunal morphotypes, represented by truncate miliolids (morphogroup c4), elongate nodosariids (morphogroup c3) and lenticular vaginulinids (morphogroup c2). Morphogroup c5 is represented by rare specimens of discoidal *Spirillina*, conical *Paalzowella* and ovate *Lagena*.

Agglutinated foraminifers of type I assemblages are represented by rare epifaunal and shallow infaunal morphotypes (about 18 % of the specimens in the assemblages) (Text-fig. 10A) of the genera *Haplophragmoides* (morphogroup ag1), *Ammodiscus* (morphogroup ag3) and *Ammobaculites*. In the Jurassic, *Ammobaculites* is interpreted as a shallow infaunal, detrital and bacterial scavenger (Nagy 1992; Tyszka 1994); however, small specimens are most common in the shallow restricted water environments with reduced salinity or oxygen (Barnard *et al*. 1981). Infaunal morphotypes are rather uncommon and represented by elongate *Reophax* (morphogroup ag2), which constitutes about 2% of the specimens in type I assemblages (Text-fig. 10A). In Mesozoic, *Reophax* is interpreted as an opportunistic (r-strategists) taxon with high vertical mobility and regarded as, most likely, deeply infaunal (Nagy 1992; Tyszka 1994). In restricted conditions of high sedimentation and high organic matter flux these foraminifers live as shallow infauna in oxygen-depleted sediment and low mesotrophic conditions (Reolid *et al*. 2008). Type I assemblages are strongly dominated by a single calcareous morphotype of morphogroup c1 (i.e., *Epistomina nuda*) with low frequencies of other morphotypes, both calcareous and agglutinated morphogroups. A high proportion of small epifaunal taxa, restricted occurrence of shallow infaunal forms and scarcity of potentially deep infaunal species suggests restricted environmental conditions, most likely caused by an abundant influx of terrestrial organic matter.

Palynological analysis (Gedl and Ziaja 2012, this issue) has demonstrated the ubiquity of terrestrial ele-



Text-fig. 9. Percentage distribution of calcareous and agglutinated foraminiferal morphogroups in the Gnaszyn sections A, B and C



Text-fig. 10. Average values of the proportions of the test type and life habit of the foraminiferal assemblages from the Gnaszyn succession; A – assemblages type I; B – assemblagrs type II

ments in all of the studied samples, albeit displaying significant vertical fluctuations in its content. According to those authors, the high frequency of cuticles and great number of Lowland sporomorphs occur in samples collected from just below and above the concretion levels, which may be related to an increased influx of terrestrial organic matter from the surrounding land. Numerous authors have shown that an increase in the organic matter content of the sediment produces an increase in the metabolic activity of the microbiota, consuming the oxygen of the pore water. The degree of oxygenation and the position of the redox boundary in the sediment control the structure of the benthic foraminiferal communites. Under conditions of very high organic influx, the redox boundary may be close to the sediment-water interface, favouring opportunistic forms dominated by epifaunal detritus feeders and shallow infaunal forms (Kuhnt *et al*. 1996; Fugagnoli 2004; Reolid *et al.* 2008, 2010).

Type I assemblages, with high ratios of opportunistic epifauna to infauna suggests rather low mesotrophic (or eutrophic) conditions of the surface waters and oxygen-depressed sea-bottom conditions. This conclusion is supported by the associated low diversity trace fossil assemblages in the same intervals (Leonowicz 2012, this issue). Type I assemblages are usually interpreted as inhabiting mid- to outer-shelf and upper continental slope (e.g., Olóriz *et al*. 2003; Reolid and Nagy 2008; Reolid *et al*. 2008).

Type II foraminiferal assemblages show much higher taxonomic diversity among both calcareous and agglutinated foraminifers. There is no single morphotype dominating the assemblage as in the case of type I assemblages (Text-fig. 9). The calcareous taxa are mainly epifaunal and shallow infaunal deposit feeders (grazing herbivores, omnivorous, and bacterial/detrital scavengers) (about 70% of the specimens) (Text-fig. 10B). The most frequent belong to morphogroup c1, including ornamented species of *Epistomina* and *Garantella.* The other calcareous morphogroups of the type II assemblages are represented by numerous fusiform and truncate morphotypes of miliolids (morphogroup c4). The miliolids (mainly *Ophthalmidium*) are typical of well-oxygenated shallow-water environments. They are intolerant of oxygen-deficient conditions, due to their imperforate tests, which impede gas exchange with the water. In modern faunas, miliolids are characteristic of the intertidal zone and inner shelf and increase in abundance with increasing food supply (Bandy 1956). Of the lenticular, biconvex, planispirally coiled nodosariids (morphogroup c2), the representatives of *Lenticulina* are the most abundant and richest taxonomically. In the early Jurassic, the lenticular morphogroup predominates in oxic sediments (Bernhard 1986); however, the cosmopolitan *Lenticulina* successfully occupied a wide range of microhabitats during the Jurassic (Bernhard 1986; Corliss and Chen1988; Koutsoukos *et al.* 1990; Rey *at al*. 1994; Tyszka 1994). Morphogroup c3 is represented by elongate, straight to arcuate multilocular morphotypes of various vaginulinids. In contrast, representatives of discoidal and conical morphotypes, as well ovate forms of *Lagena* (morphogroup c5) are less frequent. Agglutinated foraminifers are more numerous in type II assemblages than in the assemblages of type I. They include mainly epifaunal and shallow infaunal morphotypes, which constitute about 25% of the specimens in type II assemblages (Text-fig. 10B). They are represented by epifaunal, trochospirally coiled morphotypes of morphogroup ag1 (*Haplophragmoides*, *Recur-*

voides, *Trochamminoides* and *Trochammina*), planispirally coiled morphotypes also including irregularly-shaped representatives of *Glomospira* and *Ammodiscus* (morphogroup ag3) and shallow infaunal species of the genus *Ammobaculites* (morphogroup ag2). Opportunistic infauna is represented by elongate morphotypes of the genus *Reophax*, which constitutes about 5% of the specimens in type II assemblages (Text-fig. 10B).

Levels with type II foramniferal assemblages, are characterized by a smaller supply of organic terrestrial debris, and a higher content of black opaque phytoclasts, typical of marine offshore settings with a limited terrigenous influx. Cuticles are less common and the sporomorph assemblages contain a high proportion of taxa characteristic of communities growing in hinterland (Upland SEG) (Gedl and Ziaja 2012, this issue). The number of macrobenthic inhabitants, which favour periods of slower sedimentation, like some bivalves, gastropods and scaphopods, increases (Kaim 2012; Kaim and Sztajner 2012, both this issue). The trace fossils are more diverse and suggest better oxygenation of bottom sediment (Leonowicz 2012, this issue).

High taxonomic diversity and specimen abundance, and morphotype variability within type II assemblages suggests optimum living conditions in respective intervals of the succession, with high oxygen content in bottom waters and in the sediment, and with sufficient food supply (Bernhard 1986; Koutsoukos *et al.* 1990; Olóriz *et al.* 2003 among others). Such conditions could have been caused by a slower sedimentation rate and more stable, (high) mesotrophic conditions. The increased oxygenation and decreased organic influx produced a deeper redox boundary and provided optimum conditions for diverse epifaunal, shallow-infaunal and infaunal forms (Kuhnt *et al*. 1996; Fugagnoli 2004; Lemańska 2005; Reolid *et al*. 2008). Consequently, it may be assumed that type II assemblages probably inhabited neritic, inner shelf areas, with well ventilated waters caused by offshore currents.

CONCLUSION

The Middle Jurassic ore-bearing clays from Gnaszyn contain diverse foraminiferal associations, which are a good tool in the reconstruction of sedimentary environment. 56 species recognized in the studied material are represented mostly by benthic species dominated by calcareous forms.

Two types of foraminiferal assemblages (I and II) are identified, which reflect changes in lithology. These assemblages are composed of morphologically diverse taxa arranged into three agglutinated and five calcareous morphogroups. Changes in morphogroup composition are recorded by fluctuating frequencies of particular morphotypes, which apparently reflect different palaeoenvironmental conditions during the sedimentation of the deposits.

Type I assemblages are typical of dark-coloured fine-grained deposits, lying between horizons with sideritic concretions. These assemblages are characterised by low morphotype diversity (dominated by small plano/concavo-convex epifaunal deposit feeders), restricted occurrence of shallow infaunal forms and rare occurrence of deep infaunal species. Such a composition suggests low-oxygen content in both sediment and bottom waters. It may also suggest a high sedimentation rate. Such assemblages inhabited the outer shelf and upper continental slope.

Type II assemblages characterise horizons with sideritic concretions. They are characterised by high taxonomic diversity, high specimen abundance, and the presence of various epifaunal and infaunal morphotypes representing a mixed group of specialized feeding strategies. Such a composition suggests that the intervals in which Type II assemblages occur were characterised by a slower sedimentation rate, well oxidised and mixed bottom waters and sufficient food supply in the neritic inner shelf.

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REFERENCES

Bandy O.L. 1956. Ecology of foraminifera in northeastern Gulf of Mexico. *U.S. Geological Survey Professional Paper (United States)*, **274-G,** 179–204.

Barnard, T., Cordey, W.G. and Shipp, D.J. 1981. Foraminifera from the Oxford Clay (Callovian–Oxfordian of England). *Revista Espaniola de Micropaleontologia*, **13** (3), 383–462.

Bernhard, J.M. 1986. Characteristic assemblages and morphologies of benthic Foraminifera from anoxic, organic-rich deposits: Jurassic trough Holocene. *Journal Foraminifera Research*, **16**, 207–215.

Corliss, B.H. and Chen, C. 1988. Morphotype patterns of Norwegian deep sea benthic foraminifera and ecological application. *Geology*, **16**, 716–719.

Fugagnoli, A. 2004. Trophic regimes of benthic foraminiferal assemblages in Lower Jurassic shallow water carbonates from northeastern Italy (Calcari Grigi, Trento Platform, Venetian Prealps). *Palaeogeography, Palaeoclimatology, Palaeoecology*, **205**, 111–130.

Garbowska, J., Łącka, B. and Pazdro, O. 1978. Interrelation between microfauna and nature of Dogger deposits of the Częstochowa Jura (Poland). *Acta Geologica Polonica*, **23**, 98–105.

Gedl, P. and Kaim, A. 2012. Palaeoenvironmental reconstruction of Bathonian (Middle Jurassic) at Gnaszyn, Kraków-Częstochowa Upland, Poland – an introduction. *Acta Geologica Polonica*, **62** (3), 267–280

Gedl, P. and Ziaja, J. 2012. Palynofacies from Bathonian (Middle Jurassic) ore-bearing clays at Gnaszyn, Kraków-Silesia Homocline, Poland, with special emphasis on sporomorph eco-groups. *Acta Geologica Polonica*, **62** (3), 325–349.

Gedl, P., Kaim, A., Boczarowski, A., Kędzierski, M., Smoleń, J., Szczepanik, P., Witkowska, M. and Ziaja, J. 2003. Rekonstrukcja paleośrodowiska sedymentacji środkowojurajskich iłów rudonośnych Gnaszyna (Częstochowa) – wyniki wstępne. *Tomy Jurajskie*, **1**, 13–19.

Jones, R.W. and Charnock, M.A. 1985. “Morphogroups” of agglutinated foraminifera. Their life position and feeding habits and potential applicability in (paleo)ecological studies. *Revue de Paléobiologie*, **4**, 311–320.

Kaiho, K. 1994. Benthic foraminiferal dissolved-oxygen index and dissolved-oxygen levels in the modern ocean. *Geology*, **22**, 719–722.

Kaim, A. 2012. Faunal dynamics of gastropods in the Bathonian (Middle Jurassic) ore-bearing clays at Gnaszyn, Kraków-Silesia Homocline, Poland. *Acta Geologica Polonica*, **62** (3), 367–380.

Kaim, A. and Sztajner, P. 2012. Faunal dynamics of bivalves and scaphopods in the Bathonian (Middle Jurassic) ore-bearing clays at Gnaszyn, Kraków-Silesia Monocline, Poland. *Acta Geologica Polonica*, **62** (3), 381–395.

Kaminski, M.A., Gradstein, F.M., Berggren, W.A., Geroch, S. and Beckmann, J.P. 1988. Agglutinated foraminiferal assemblages from Trinidad: taxonomy, stratigraphy and paleobathymetry. *Abhandlungen der Geologischen Bundesanstalt*, **41**, 155–228.

Kitazato, H. 1988. Ecology of benthic foraminifera in the tidal zone of a rocky shore. *Revue de Paléobiologie*, *Spec*., **2**, 815–825

Kopik, J. 1998. Lower and Middle Jurassic of the north-eastern margin of Upper Silesian Coal Basin. *Biuletyn Państwowego Instytutu Geologicznego*, **378**, 67–131.

Koutsoukos, E.A.M., Leary, P.N. and Hart, M.B. 1990. Latest Cenomanian-Earliest Turonian low oxygen tolerant benthic foraminifera: a case study from the Sergipe Basin (NE Brazil) and the Western Anglo-Paris Basin (Southern England). *Palaeogeography, Palaeoclimatology, Palaeoecology*, **7**, 145–177

Kuhnt, W., Moullade, M. and Kaminsky, M. 1996. Ecological Structure of deep sea agglutinated foraminifera – a review. *Revue de Micropaléontologie*, **39** (4), 271–281.

Lemańska, A. 2005. Comparison of deep-water agglutinated foraminifera from the hemipelagic variegated shales (Lower Turonian-Lower Santonian) and the turbiditic Godula beds (Upper Santonian-Campanian) in the Lanckorona-Wadowice area (Silesian Unit, Outer Carpathians, Poland). *Studia Geologica Polonica*, **124**, 259–272.

Leonowicz, P. 2012. Sedimentology and ichnology of Bathonian (Middle Jurassic) orebearing clays at Gnaszyn, Kraków-Silesia Homocline, Poland. *Acta Geologica Polonica*, **62** (3), 281–296.

Loeblich, A.R. and Tappan, H. 1987. Foraminifera genera and their classification. **1**, 970 pp. **2**, 212. Van Nostrand Reinhold Company; New York.

Majewski, W. 2000. Middle Jurassic concretions from Częstochowa (Poland) as indicators of sedimentation rates. *Acta Geologica Polonica*, **50**, 431–439

Matyja, B.A. and Wierzbowski, A. 2003. Biostratygrafia amonitowa formacji częstochowskich iłów rudonośnych (najwyższy bajos-górny baton) z odsłonięć w Częstochowie. *Tomy Jurajskie*, **1**, 3–7.

Nagy, J. 1992. Environmental significance of foraminiferal morphogroups in Jurassic North Sea deltas. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **95**, 111–134.

Nagy, J., Gradstein, F.M., Kaminsky, M.A. and Holbourn, A.E. 1995. Foraminiferal morphogroups paleoenvironment and new taxa from Jurassic to Cretaceous strata of Thakkhola, Nepal. In: M.A. Kaminski, S. Geroch and M.A. Gasiński (Eds), Proceeding of Fourth Workshop on Agglutinated Foraminifera. Kraków, Poland. September, 1993. *Grzybowski Foundation Special Publication*, **3**, 181–209.

Nagy, J., Reolid, M. and Rodriguez-Tovar, F.J. 2009. Foraminiferal morphogroups in dysoxic shelf deposits from the Jurassic of Spitsbergen. *Polar Research*, **28**, 214–221.

Oloriz, F., Reolid, M., Rodriguez-Tovar, F.J. 2003. Palaeogeographic and stratigraphic distribution of Mid-Late Oxfordian foraminiferal assemblages in the Prebetic Zone (Betic Cordillera, southern Spain). *Geobios*, **36,** 733–747.

Pazdro, O. 1954. Próby rozpoziomowania iłów rudonośnych na podstawie mikrofauny. (Badania geologiczne iłów rudonosnych Jury Krakowsko –Wieluńskiej). *Biuletyn Państwowego Instytutu Geologicznego*, **1**, 173–180.

Pazdro, O. 1959. On the stratigraphic distribution of the Miliolidae in the Middle Jurassic of Poland. *Acta Geologica Polonica*, **9**, 343–381.

Pazdro, O. 1969. Middle Jurassic Epistominidae of Poland. *Studia Geologica Polonica*, **27**, 7–92.

Phleger, F.B. and Soutar, A. 1973. Production of benthic foraminifera in three East pacific oxygen minima. M*icropaleontology*, **19**, 110–115.

Reolid, M. and Nagy, J. 2008. Jurassic transgressive–regressive cycles in carbonate and siliciclastic shelf facies: different response of foraminiferal assemblage trends to sea-level changes. *Grzybowski Foundation Special Publication*, **13**, 199–213.

Reolid, M., Nagy, J., Rodriguez-Tovar, F.J. and Oloriz, F. 2008. Foraminiferal assemblages as palaeoenvironmental bioindicators in Late Jurassic epicontinental platforms: Relation with trophic conditions. *Acta Palaeontologica Polonica*, **53** (4), 705–722.

Reolid, M., Rodriguez-Tovar, F.J., Nagy, J. and Oloriz, F. 2008a. Benthic foraminiferal morphogroups of mid to outer shelf environments of the Late Jurassic (Prebetic Zone, Southern Spain): characterization of biofacies and environmental significance. *Palaeogeography, Palaeoecology, Palaeoclimatology*, **261**, 280–299.

Reolid, M., Nagy, J. and Rodriguez-Tovar, F.J. 2010. Ecostratigraphic trends of Jurassic agglutinated foraminiferal assemblages as a response to sea-level changes in shelf deposits of Svalbard (Norway). *Palaeogeography, Palaeoecology, Palaeoclimatology*, **293**, 184–196.

Rey, J., Bonnet, L., Cubaynes, R., Qajoun, A. and Ruget, C. 1994. Sequence stratigraphy and biological signals: statistical studies of benthic foraminifera from Liassic series. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **111,** 149–171.

Sagasti, G. and Ballent, S. 2002. Microfaunal features of a marine transgression: the Agrio Formation (Lower Cretaceous), Neuquén Basin, Argentyna. *Geobios*, **35**, 721–734

Smoleń, J. 2004. Interpretacja paleośrodowiska sedymentacji środkowojurajskich iłów rudonośnych Gnaszyna na podstawie zespołów otwornic. In: J. Muszer (Ed.), XIX Konferencja naukowa paleobiologów i biostratygrafów PTG: "Zapis paleontologiczny jako wskaźnik paleośrodowisk", Wrocław 16–18 września 2004 r. pp. 53–55.

Smoleń, J. 2006. Palaeoenvironmental significance of the foraminiferal assemblages from the Middle Jurassic deposits of Częstochowa area. *Volumina Jurassica*, **4**, 136–137.

Szczepanik, P., Witkowska, M. and Sawiowicz, Z. 2007. Geochemistry of Middle Jurassic mudstones (Kraków-Częstochowa area, southern Poland): interpretation of the depositional redox conditions. *Geological Quarterly*, **51**, 57–66

Szydło, A. 2004. The distribution of agglutinated foraminifera in the Cieszyn Basin, Polish Outer Carpathians). *Grzybowski Foundation Special Publication*, **8**, 461–470.

Szydło, A. 2005. Foraminifers of the Cieszyn Beds from the Cieszyn Foothills (Outer Carpathians). *Biuletyn Państwowego Instytutu Geolologicznego*, **415**, 59–95.

Tyszka, J. 1994. Response of Middle Jurassic benthic foraminiferal morphogroups to dysoxic/anoxic conditions in the Pieniny Klippen Basin, Polish Carpathians. *Palaeogeography, Palaeoecology, Palaeoclimatology*, **110**, 55–81.

Van Der Zwaan, G.J. and Jorissen, F.J. 1991. Biofacies patterns in river-induced shelf anoxia. In: R.V. Tyson and T.H. Pearson (Eds), Modern and Ancient Continental Shelf Anoxia. *Geological Society, Special Publication*, **58**, 65–82.

Zatoń, M., Marynowski, L., Szczepanik, P., David, P.G. Bond, D.P.G. and Wignall P.B. 2009. Redox conditions during sedimentation of the middle Jurassic (Upper Bajocian–Bathonian) clays of the Polish Jura (south-central Poland). *Facies*, **55**, 103–114.

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Appendix I

An alphabetic list of foraminifera from studied sections of the ore-bearing clays at Gnaszyn is presented below.

Ammobaculites fontinensis (Terquem, 1870)
Ammobaculites sp.
Ammodiscus cf. *glumaceus* Gerke & Sossipatrova, 1961
Ammodiscus sp.
Astacolus matutinus (d'Orbigny, 1850)
Astacolus franconicus (Gümbel, 1862)
Astacolus suprajurassicus (Schwager, 1865)
Citharina cf. *oolithica* (Schwager, 1887)
Citharina sp.
Dentalina sp.
Epistomina cosifera Terquem, 1883
Epistomina nuda Terquem, 1883
Epistomina pentarima Dain, 1953
Epistomina regularis Terquem, 1883
Frondicularia sp.
Garantella aff. *stellata* Kaptarenko, 1959
Geinitzinita nodosaria (Terquem, 1870)
Glomospira gordialis (Jones & Parker, 1860)
Globuligerina bathoniana (Pazdro, 1969)
Haplophragmoides sp.
Ichtyolaria cf. *nympha* Kopik, 1969
Ichtyolaria sp.
Lagena globosa (Montagu, 1803)
Lenticulina (*Astacolus*) *argonauta* (Kopik, 1969)
Lenticulina (*Astacolus*) *dictyotes dictyotes* (Deecke, 1884)
Lenticulina helios (Terquem, 1869)
Lenticulina kujaviana Kopik, 1969
Lenticulina mamillaris (Terquem, 1886)
Lenticulina muensteri (Roemer, 1839)
Lenticulina quenstedti (Gümbel, 1862)
Lenticulina cf. *ruesti* (Wiśniowski, 1890)
Lenticulina volubilis Dain, 1958
Nodosaria dispar Franke,1936
Nodosaria plicatilis Wisniowski, 1890
Nodosaria pulchra (Franke, 1936)
Ophthalmidium carinatum agglutinans Pazdro, 1958
Ophthalmidium carinatum terquemi Pazdro, 1958
Paalzowella pazdroe Bielecka & Styk, 1969
Paleomiliolina czestochowiensis (Pazdro, 1959)
Paleomiliolina rawiensis (Pazdro, 1959)
Palmula deslongchampsi (Terquem, 1864)
Planularia eugenii (Terquem, 1864)
Planularia prava (Terquem, 1870)
Recurvoides sp.
Reinholdella crebra Pazdro, 1969
Reophax fusiformis (Willamson, 1858)
Reophax sterkii Hausler, 1890
Reophax sp.
Saracenaria oxfordiana Tappan, 1955
Saracenaria tricostata (Mitjanina, 1955)
Spirillina radiata Terquem, 1886
Spirillina sp.
Trochammina sp.
Trochamminoides sp.
Trocholina conica Schlumberger,1898
Vinelloidea infraoolithica (Terquem, 1870)

Appendix II

Below, lists of distinguished foraminifera species representing particular morphgroups are presented.

Morphogroup ag1:
Haplophragmoides sp.
Recurvoides sp.
Trochammina sp.
Trochamminoides sp.
Morphogroup ag2:
Ammobaculites fontinensis (Terquem)
Ammobaculites sp.
Reophax fusiformis (Willamson)
Reophax sp.
Reophax sterkii Hausler
Morphogroup ag3:
Ammodiscus cf. *glumaceus* Gerke & Sossipatrova
Ammodiscus sp.
Glomospira gordialis (Jones & Parker)
Morphogroup c1:
Epistomina cosifera Terquem
Epistomina nuda Terquem
Epistomina pentarima Dain
Epistomina regularis Terquem
Garantella aff. *stellata* Kaptarenko
Reinholdella crebra Pazdro
Morphogroup c2:
Astacolis matutinus (d'Orbigny)
Astacolus franconicus (Gümbel)
Astacolus suprajurassicus (Schwager)
Lenticulina (*Astacolus*) *argonauta* (Kopik)
Lenticulina (*Astacolus*) *dictyotes dictyotes* (Deecke)
Lenticulina helios (Terquem)
Lenticulina kujaviana Kopik
Lenticulina mamillaris (Terquem)
Lenticulina muensteri (Roemer)
Lenticulina quenstedti (Gümbel)
Lenticulina cf. *ruesti* (Wiśniowski)
Lenticulina volubilis Dain
Planularia eugenii (Terquem)
Planularia prava (Terquem)
Saracenaria oxfordiana Tappan
Saracenaria tricostata (Mitjanina)
Morphogroup c3:
Citharina cf. *oolithica* (Schwager)
Citharina sp.
Dentalina sp.
Frondicularia sp.
Geinitzinita nodosaria (Terquem)
Ichtyolaria cf. *nympha* Kopik
Ichtyolaria sp.
Morphogroup c4:
Nodosaria dispar Franke
Nodosaria plicatilis Wiśniowski
Nodosaria pulchra (Franke)
Ophthalmidium carinatum agglutinans Pazdro
Ophthalmidium carinatum terguemi Pazdro
Paleomiliolina czestochowiensis (Pazdro)
Paleomiliolina rawiensis (Pazdro)
Palmula deslongchampsi (Terquem)
Morphogroup c4:
Lagena globosa (Montagu)
Paalzowella pazdroe Bielecka & Styk
Spirillina radiata Terquem
Spirillina sp.
Trocholina conica Schlumberger
Vinelloidea infraoolithica (Terquem)