Miliammina gerochi n.sp. – A MIDDLE JURASSIC RZEHAKINID (FORAMINIFERIDA) FROM QUASI-ANAEROBIC BIOFACIES

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Abstract: Miliammina gerochi n.sp. is so far the oldest reported representative of the superfamily Rzehakinacea from Jurassic sediments. Its occurrence is confined to the lower part of Harcygrund Shale Formation in the Pienny Klippen Belt (Western Carpathians, Poland). This formation is represented by a “black shale” facies developed during the late phase of the Aalenian/Bajocian “regional anoxic/dysoxic event”. Overall biofacies relationships indicate that M. gerochi n.sp., as a benthic agglutinated foraminifer, inhabited normal saline, middle to outer neritic palaeoenvironments under extremely dysoxic or even suboxic, food-rich conditions, and gradually disappeared with improving bottom water oxygenation, enhanced density of macrofaunal bioturbation, increasing sedimentation rate, and probably deepening of the basin. The Miliammina gerochi Assemblage marks a very productive phase in the Klippen Basin history. Based on functional morphology and studies of modern Miliammina species, it can be speculated that this Jurassic species preferred an endobenthic microhabitat and probably thrived on/within benthic bacterial mats associated with suboxic conditions. Comparison between different habitats successfully colonized by rzehakinids suggests that since the Jurassic till the present, this group preferred stressed environments rich in food. Evolutionary relationships remain uncertain due to the lack of reported ancestors.

Abstract: Wczesobajociańska Miliammina gerochi n.sp., aglutynująca otworówka bentoniczna, jest jak dotychczas najstarszym znanymi przedstawicielem nadrodziny Rzehakinacea. Jej występowanie ograniczone jest wyłącznie do dolnej części formacji łupków z Harcygrundu w pienińskim pasie składowym (Karpaty Zachodnie, Polska). Formacja ta odsłania się w postaci facji „czarnych łupków”, reprezentujących późną fazę regionalnego wydarzenia bezlegenowego na pograniczu aalen i bajoc. Ogólna relacja biofazialna wskazuje, że M. gerochi n.sp. zasiedlała morze o normalnym zasoleniu, w środkowej i zewnętrznej strefie nerytycznej, w warunkach eutroficznych, przy bardzo silnym zubożeniu w tlen. Stopniowy zanik tego gatunku należy wiązać z poprawą natlenienia, wzrostem gęstości zerowania makrofauny bentonicznej, wzrostem tempa sedimentacji oraz prawdopodobnie z pogłębianiem się basenu. Zespół z M. gerochi n.sp. wskazuje na bardzo produktywną fazę w historii basenu składowego. Na podstawie morfologii tej formy oraz na podstawie badań współczesnej Miliammina można sugerować, że opisywany gatunek preferował endobentoniczny styl życia, zasiedlając maty bakteryjne związane z warunkami subokrewnymi. Porównanie różnych środowisk skutecznie kolonizowanych przez rzehakinidy wskazuje, iż grupa ta od jury do dzisiaj preferowała bogate w pokarm środowiska stresowe. Pochodzenie tej grupy i jej nowego gatunku nie zostało dotychczas wyjaśnione z powodu braku jednoznacznych podobów.

Key words: Miliammina gerochi n.sp., Rzehakinacea, benthic foraminifera, functional morphology, anoxic/dysoxic palaeoenvironment.

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INTRODUCTION

There is an increasing amount of evidence to suggest that the evolution of foraminifera and other marine faunas is strongly related to anoxic facies. There is little doubt that fluctuations of the bottom- and interstitial-water oxygenation are especially responsible for changes in faunal associations. The widespread distribution of black shale facies often coincides with the disappearance and/or appearance of certain foraminiferal taxa or even whole groups. Some benthic foraminifera are limited to these facies, and are only present when oxygenation is low and disappear with improvements of bottom water ventilation (Kaiho, 1991).

Such assemblages have already been reported from “the Aalenian–Bajocian regional anoxic/dysoxic event” in the Pienny Klippen Basin (Tyszka & Kamiński, 1995). The as-
semblages are dominated by agglutinated foraminifera, such as *Vernerinella pientinica* Tyszyka & Kaminski and *Trocaminina globoconica* Tyszyka & Kaminski. These two species occur only within a certain horizon of black shales and are missing from all other facies. A similar assemblage has also been identified within the “black shales” of another lithostratigraphic unit (Harczygrund Shale Formation), but associated with the same “regional anoxic/dysoxic event” (Tyszyka, 1995). It is interesting that this assemblage is dominated by one species of genus *Miliammina*, a representative of Rzehakinaeae. This superfamily has thus far not been reported from the Middle Jurassic. The main purpose of this study is to describe this new species of *Miliammina*, and to evaluate factors controlling the distribution of this species and the associated fauna.

**METHODS**

A total of 14 surface samples from the Harczygrund Shale Formation of the Branisko Succession were collected for this study. The sample processing consisted of drying, weighing out 250 g samples, and disintegrating in a solution of sodium carbonate. The disintegrated samples were washed through sieves with mesh diameters of 105 and 600 μm. The foraminifera were picked from fractions 105–600 μm.

**GEOLOGICAL SETTING**

The study area is confined to the Polish part of the Pieniny Klippen Belt, which represents the axial part of the Western Carpathians (Fig. 1). *Miliammina gerochi* n.sp. has been identified from the Harczygrund Shale Formation, which was formally distinguished by Birkenmajer (1977). This unit was separated by him from the “Posidonien-schichten” of Uhlig (1890), and Horwitz (1937) and corresponds to the *Posidonia* shales or *Posidonia* member in the Kysuca Succession in Slovakia (Scheibner, 1968; see Birkenmajer, 1977). The Harczygrund Shale Formation belongs to the Dunajec Group and is recognized in the Branisko, Pieniny, and Magura successions (Fig. 2). These sedimentary successions were deposited within the Pieniny Klippen Basin, which represented a part of the Western Tethys (Birkenmajer, 1960, 1977).

The formation within the Branisko Succession has been studied here. It is characterized by dark-grey to black shaly marlstones, silty marls and shaly marly limestones. The shales often contain thin shells and imprints of the bivalve
**Fig. 2.** Location of the Harcygrund Shale Formation within Toarcian to Lower Bajocian lithostratigraphic scheme of the Klippen successions in the Pienniny Klippen Belt of Poland (after Birkenmajer, 1977)

*Bositra buchi* (Roemer), fine mica flakes, small pyrite concretions, and plant detritus (especially in the lower part of the unit). The thickness of the formation ranges from 70 to 100 m. The lower boundary with the Skrzypny Shale Formation is undefined (tectonic), the upper one is usually tectonic. A few localities reveal a transitional contact with the overlying Podzamcze Limestone Formation (Birkenmajer, 1977). The early Bajocian age of the Harcygrund Shale Formation is based on ammonites and represented by a biostratigraphical interval from the *Soninina sowerbyi* Zone, through *Otoites sauezi* Zone, to the lowest part of *Stephanoceras humphriesianum* Zone (Myczyński, 1973).

**Locality**

Samples collected to the present studies have been taken from four localities (Figs. 1, 3):

**Harcygrund Valley.** Left side of the lower part of the valley (Myczyński, 1973: p. 28-29, figs. 1, 5, 6; Birkenmajer, 1977: figs. 7H, 16A; Tyszka, 1995: figs. 1, 2B, 22); type section of the formation; a 8 meter thick sequence of dark-grey marly limestones intercalated with dark-grey to black, often sandy marlstones is exposed; maximum thickness of limestone bands: 30–40 cm, usually 10–20 cm.

**Żłóbowe Potoczki.** Left tributary stream of the Niedzi czanka Stream near Niedzica village (Tyszka, 1995: figs. 1, 2B, 23); the left bank of the middle part of the Żłóbowe Potoczki, exposed 2 m above the stream; a two-meter thick section of dark-grey to black shaly marlstones; layers dip 175/60, the whole complex tectonically contacts with vertical bands of green radiolaries (Czajakowa Radiolarite Formation); shales rarely intercalated with thin bands of dark-grey marly limestones showing a sort of “boudinage”-structures.

**Podzamcze – right bank of the Dunajec River.** Near Niedzica, below the castle; 2–3 m thick complex of dark-

**Fig. 3.** Correlation of examined sections of the Harcygrund Shale Formation with defined foraminiferal assemblages; A, B, C – lithologic units described in text; ZPH-, HAH-samples revealing the *Milaminia gerochi* Assemblage (for detailed sections see Tyszka, 1995)
grey and black shaly marlstones intercalated with thin (2–5 cm) bands of dark-grey spotty limestones (see Tyszka, 1995: figs. 1, 2B, 24); dark-grey marls prevail over hard spotty limestones. This complex has been attributed to the Harcygrund Shale Formation (see Birkenmajer, 1977). Previously, the upper part of this outcrop (above grey-blue spotted limestones and marls of the Podzamcze Formation) was identified as the lowermost unit of the "Supra-Posidonia Beds" (Myczynski, 1973: p. 51).

Cisowiec. East side of the Krośnica–Katy road cutting through the Długa Grapa near Flaki (Kasiński et al., 1981: fig. 1b; Tyszka, 1995: figs. 1, 2B, 25); a 2 m thick section of dark-grey shaly marlstones exposed in the core of the normal inclined fold; anticalinal flanks of the fold are composed of grey spotty limestones and marlstones of the Podzamcze Formation. The passage from dark-grey marlstones to overlying thin to thick bands of grey limestones intercalated with marlstones may represent the boundary between the Harcygrund and Podzamcze formations.

Sedimentary and trace-fossil structures

The Harcygrund Shale Formation can be subdivided into three informal lithologic units (facies) (Fig. 3), i.e.: (Unit A) a complex dominated by black marly shales (mudstones) with some intercalations of thin dark-grey marly arenaceous limestones (localities: Żłobowe Potoczki, upper part of the type section in the Harcygrund Valley); (Unit B) a unit formed of moderate to thick bands of dark-grey marly limestones intercalated with dark-grey to black arenaceous marly shales (lower and middle parts of the Harcygrund Valley locality); (Unit C) a complex dominated by dark-grey marly shales partly intercalated with thin dark-grey spotted limestones, representing passage beds to the Podzamcze Limestone Formation (localities: Cisowiec, Podzamcze).

Unit A. Shales of Unit A have revealed fine varve-like lamination caused by changes in the pronounced amount of fine arenaceous fraction of quartz and calcite grains. Silt and clay form either flaser-like structures or laminae containing a high number of small and thin bivalve filaments (Bositra buchi) and sponge microscleres (rhax-type). The degree of bioturbation depends on the interval examined and varies from non-bioturbated (ichnofabric index 1 sensu Droser & Bottjer, 1986) to moderately bioturbated (ichnofabric index 3). Usually, the lamination structures are slightly disturbed by tiny Chondrites-like burrows (ichnofabric index 2). These burrows are either filled with lighter-grey and coarser grains or with a black fine central part and a lighter and coarser structure ("halo-structure"). The maximum burrow diameter (MBD) reaches 1–2 mm in the upper part of the type locality (Harcygrund Valley). Microfacies are usually represented by arenaceous filament-spiculite marly wackestone.

Unit B. Sedimentary structures of Unit B show a microscale cross-lamination and normal gradation of fine sandy grains. Some samples have revealed frequent larger shells of Bositra, which are either broken or unbroken. Sponge microscleres are also relatively common. These primary structures are often more or less disturbed by burrows (ichnofabric indices 2–5). Trace fossils are represented mainly by Chondrites and small Planolites. MBD ranges from 3 to 6 mm.

Unit C. Structures of Unit C do not distinctly differ from unit B but they are usually overprinted by bioturbation (ichnofabric indices 4–5). Ichnotaxa and MBD are very similar to those of unit B, locally, rare Zoophycos can be recognized (Podzamcze locality). Microfacies of both B and C units are classified as arenaceous spiculite-filament marly wackestone.

BENTHIC FORAMINIFERAL ASSEMBLAGES

Benthic foraminiferal associations are especially manifested by the distribution of two recurrent foraminiferal assemblages named after characteristic taxa, i.e. Miliammina gerochi n.sp. and Rhabdammina–Reinhodella–Lenticulina assemblages (Fig. 3).

Miliammina gerochi n.sp. Assemblage. This assemblage has been distinguished at two localities (Figs. 1, 3): Żłobowe Potoczki (samples: ZPH-1, -2, -5) and Harcygrund Valley (HAH-9, -10). The assemblage is characterized by the occurrence of a relatively high proportion of Miliammina gerochi (18–54%; mean 39.4%) associated with other agglutinated foraminifera limited to rare astrophizids (Rhabdammina/Hyperammina) and single specimens of Ammobaculites, Recurvoides, Trochammina. Calcareous foraminifera are represented by nodosariids dominated by Lenticulina spp. and Laevidentalina spp., associated with a lower number of Astacolus, Froncolitaria, Nodosaria (including N. regulars), and Vaginalinopsis; additionally, by variable proportions of poorly preserved epistominids (2–25%) and low proportions of ophthalmoinds, polymorphinids, and rau-mulids. Epistominids may resemble smooth-test Reinhodella spp. and ornamented Epistomina spp. Single specimens of Epistomina arcana Antonova and E. semiornata (Schwager) have been identified.

Associated microfossils are represented by a moderate number of ostracods. Surprisingly, relatively high proportions (20–40%) of ornamented ostracods have been found. These sculptured ostracods may be attributed to the Progonocytheridae. Smooth ostracods are represented by the Bairdiaea, Schuleridae (genus Praeschuleridea), and Cytherellidae (genus Cytherella). Moreover, sponge microscleres comprise a distinctive part of the benthic assemblage. The spicules are dominated by one axis forms, triactines, tetractines, and kidney- or bean-like forms. The number of spicules varies from single (Żłobowe Potoczki locality) to thousands (Harcygrund Valley locality) per 250 g sample. The assemblage also contains single echinoderm fragments and small gastropods, which are similar to those found in the upper part of the Skrzypny Shale Formation. Single to frequent spherical casts of radiolaria have also been found.

Rhabdammina–Reinhodella–Lenticulina Assemblage. This assemblage has been recognized at four localities: Harcygrund Valley (samples: HAH-2, -4, -7), Żłobowe Potoczki (ZPH-7), Podzamcze-right bank of the Dunajec River (LP-2, -3, -4), and Cisowiec (CH-2, -3) (Figs. 1, 3). Agglu-
tinated foraminifera are dominated by tubular astrophizids (Rhabdammina/Hyperammina) and rare Trochammina, Reophax, Ammobaculites, and Ammodiscus. Milianammina gerochi does not occur within this association. Poorly preserved, often recrystallized specimens of epistominids are represented by smooth-test Reinholdella. Nodosariids composing a main part of the assemblage are dominated by Lenticularina and Laevidentailina. Other nodosariid genera, such as Asterolites, Nodosaria, Pseudonodosaria, Vaginulinopsis, are confined to single or frequent occurrences. Other groups are limited to single specimens of Ramulina laevis and Spirillina spp.

Associated microfossils are similar to the Milianammina gerochi n.sp. Assemblage, and are represented by a moderate number of ostracods, a variable amount of sponge spicules, and echinoderm fragments (including frequent crinoidal remains and echinoid spines). In addition to benthic fossils, single radiolaria have also been found.

**Facial and biofacial succession.** The foraminiferal succession of the Harcygrund Shale Formation has been subdivided into two successive assemblages: the Milianammina gerochi Assemblage and the Rhabdammina–Reinholdella–Lenticularina Assemblage. These assemblages can be used to help recognize stratigraphic succession of strata within the strongly folded formation. There is a co-occurrence of the same species of epistominids, i.e., Epistomina arcanana and E. seminornata in the Milianammina gerochi Assemblage of the Harcygrund Formation, and in the Epistomina n.sp. Assemblage in the upper part of the Skrzypn Shale Formation (Tyszka, 1994b). These species are limited only to the interval in the Klippen successions and most likely, represent the lower part of the lower Bajocian. There are single appearances of small gastropods very similar to those that are common in the Skrzypn Formation. These gastropods have not been recognized in other stratigraphic intervals. It appears that the Milianammina gerochi Assemblage may correspond to the assemblage with epistominids in the upper part of the Skrzypn Shale Formation (Fig. 2; Tyszka, 1994b).

Occurrence of a comparable assemblage with abundant calcareous foraminifera represented by Quinqueloculina (with a test shape similar to Milianammina) associated with epistominids was reported from the Skrzypn Shale Formation of the Czertezik Succession in the Slovakian part of the Klippen Belt (Scheibnerová, 1965) representing an interval from the Ludwigia murchisonae to Soninia sowerbyi zones (Hyperlioceras discites Subzone) (Scheibner, 1964). The Harcygrund Shale Formation is dated as representing the time span from the S. sowerbyi Zone up to the lower part of the Stephanoceras humphriesianum Zone. Therefore, it is likely that the Milianammina Assemblage corresponds to the S. sowerbyi Zone. Support for this interpretation is given by the finding of ammonite Hyperlioceras cf. discites (Waagen) in the upper part of the type section in the Harcygrund Valley (Myczynski, 1973), i.e., in the same interval with the Milianammina gerochi Assemblage. Thus this foraminiferal assemblage probably represents the oldest part of the Harcygrund Shale Formation (Fig. 3).

**PALAEOECOLOGICAL IMPLICATIONS OF THE Milianammina gerochi n.sp.**

**Oxygenation and organic matter input.** Foraminifera of the Harcygrund Shale Formation are represented by relatively high abundances of inferred endobenthic and epibenthic morphgroups. The Milianammina gerochi Assemblage consists of 60–75% endobenthic forms dominated by rzhahnikids with M. gerochi and nodosariids especially represented by Lenticularina and Laevidentailina, with a low contribution of Pseudonodosaria and Frondicularia. Epibenthic forms are dominated by epistominids and miliolids. Agglutinated tubular foraminifers (astrophizids) are strongly restricted in occurrence.

Surprisingly, a high proportion of rzhahnikids represented by M. gerochi distinguishes this association from others recognized in this study. This genus even reaches up to 50–52% of the whole foraminiferal assemblage in the lowermost part of the succession exposed at Złobowe Potoczki (Fig. 3: samples ZPH-1, -2). Interestingly, the same interval is represented by black marlstones revealing either a fine varve-like laminations, non-disturbed by bioturbation or laminations with thin Chondrites-like burrows that only slightly disturb the primary sedimentary laminations.

It is likely that such a benthic assemblage indicates a high food availability and a very low oxygenation of the bottom water. Locally preserved fine laminations and absent or sparse echinoderm remains with abundant meiofauna (foraminifers) suggest suboxic to extremely dysoxic conditions (sensu Tyson & Pearson, 1991). Relatively less abundant deep endobenthic foraminifers probably responded to a rise of the redox potential discontinuity which would have been located just beneath the water/sediment interface. This is also supported by a relatively high proportion of ornamented, epibenthic ostracods. Periodical anoxia and a high food availability probably adversely affected astrophizids which are usually reported from mesotrophic environments (A. Gooday, personal communication).

It remains uncertain what kind of nutrition influenced the mass occurrences of the Milianammina gerochi n.sp. Assemblage. Kuhn and Kaminoki (1990) have reported that rzhahnikids are rare or absent in Late Cretaceous well-oxygenated environments but occur in high abundances only in oxygen-deficient environments with a high input of organic matter. Modern Milianammina is interpreted as an endobenthic form preferring the detrital/bacterial feeding strategy (Jones & Charnock, 1985). It can be speculated that enhanced numbers of benthic bacteria favoured large populations of these foraminifers. This phenomenon may be related to the “edge effect” which has recently been recognized at the upper boundary of the Central California Oxygen Minimum Zone (Mullins et al. 1985; Thompson et al., 1985; Vercoutere et al., 1985). Passing through extremely and severe dysoxic conditions (sensu Tyson & Pearson, 1991) causes the appearance of bacterial mats and an increase in faunal density. It is likely that benthic bacterial mats created a nutrition-rich subenvironment for this assemblage.

**Opportunism.** High dominance associated with “flood occurrences” of Milianammina gerochi n.sp. fits to the r selec-
tion model of MacArthur and Wilson (1967). Early reproduction in response to a high food availability seems to be a probable explanation for such high abundances of this species. The association of some opportunistic foraminifera with high organic input and oxygen deficiency has been reported to be typical for oxygen minimum zone assemblages (Pfleger & Soutar, 1973; Koutsoukos et al., 1990; Sen Gupta & Machain-Castillo, 1993; Kaminski et al., 1995).

Palaeobathymetric preferences. It is of interest to evaluate the palaeobathymetric preferences of the *Miliammina gerochi* Assemblage. The co-occurrence of ornamented epistomids, low percentage of astrohizids, relatively high proportions of sculptured ostracods and single well-preserved parts of crinoid columnals suggest a relatively shallow-water environment, which may be attributed to the middle-outer neritic zone. This paleodepth probably changed with the appearance of gravity flows, an enhanced number of astrohizids and the disappearance of the shallow water *Miliammina* (Tyszka, 1994a, b). This depositional and palaeoenvironmental turnover may be attributed to the deepening of this part of the basin possibly enhanced by tectonic activity. The *Rhabdammina-Reinholdella-Lenticulina* assemblage may therefore represent a mixed assemblage with some amount of redeposited microfauna (possibly the epistomids).

This change is also well recognizable within successions of maximum burrow diameters (MBD) and bioturbation indices, manifested by an increase of both indicators upwards the sequence, suggesting a slight but progressive improvement in oxygenation. It may have been a response to better mixing of the bottom water through gravity flows and bottom currents induced by palaeotopographic changes of the basin Tyszka, 1994a.

**DISCUSSION**

The evolutionary relationships of *Miliammina gerochi* n.sp. remain uncertain owing to the lack of reported ancestors and a gap in the record of rzechnikids until the late Callovian (Seibold & Seibold, 1960; Oesterle, 1968). It is even uncertain whether *Miliammina* originated from an agglutinated foraminiferal lineage or came directly from the superfamily Miolacea already well established in the Jurassic represented by the genus *Quinqueloculina*. Support for the latter explanation is provided by the contemporaneous appearance of *Quinqueloculina* in the same basin within a shallower palaeobathymetric zone of the Czertezik Succession (Scheibnerová, 1965).

Modern *Miliammina* is a typical and often predominant form in very shallow-water environments (littoral to outer sublittoral) ranging from estuaries, through lagoons, to marshes and mangroves. For instance, modern *Miliammina fusa* with its marsh and marginal sea preferences appears as one of the most euryhaline species, tolerating salinities from 0 to 23 per mille (Boltovskoy & Wright, 1976; Jones & Charnock, 1985). Another recent species, *Miliammina arenacea*, dominates within cold-water upper bathyal assemblages of the Antarctic slope (Lindenberg & Auras, 1984). Scheibnerová (1976) interpreted the Aiptan *Miliammina inferior* Ludbrook as an inner sublittoral form, found in basin margin and intrabasinal ridge facies of the Cretaceous Great Australian Basin. The Late Jurassic *Miliammina jurassica* (Haessler) was often reported from the shallow sponge bioherm facies ("Schwammfazies") and seldom from the deeper "Bankfazies" (Seibold & Seibold, 1960; Oesterle, 1968). In the present study, the overall faunal benthic associations also suggest shallow-water preferences for the Jurassic *Miliammina gerochi* n.sp.

It is interesting that from the Jurassic until the Holocene, *Miliammina* (or rzechnikids in general) have successfully colonized stressed environments, such as suboxic habitats, hyposaline marshes and lagoons sponge bioherms, and cold water bathyal depths. All these habitats have something in common, i.e., a high food supply.

The *Miliammina gerochi* n.sp. Assemblage marks a very productive phase in the Klippen Basin history. The high organic matter input associated with the development of anoxic conditions was probably linked with the formation of the oxygen minimum zone and hydrodynamic turnover from stratified, stagnant water column to more dynamic "upwelling" type circulation. This model is additionally supported by the contemporaneous formation of phosphatic concretions within the middle neritic part of the basin (upper part of the Skrzynska Shale Formation). It seems likely that the palaeoenvironmental change was brought about by seal level rise and deepening of the Braniško palaeobathymetric zone within the Klippen Basin (Tyszka, 1995; Tyszka & Kaminski, 1995). This deepening is indicated by: (a) disappearance of *Miliammina gerochi*; (b) disappearance of ornamented epistomids; (c) increasing proportion of astrohizids.

**SYSTEMATIC PALEONTOLOGY**

Order FORAMINIFERA Eichwald, 1830
Suborder TEXTULARINA Delage & Herouard, 1896
Superfamily RZEHAKINACEA Cushman, 1933
Family RZEHAKINIDAE Cushman, 1933
Genus Miliammina

*Miliammina gerochi* n.sp.
Fig. 4 A–D; Fig. 5 A–F

**Etymology:** In memory of Professor Stanisław Geroch.

**Material:** Holotype (sample ZPH-2) and 7 paratypes (samples

Fig. 4. SEM photographs. A. *Miliammina gerochi* n.sp. – holotype; sample ZPH-2; 1 – side view; 2 – oblique view; 3 – apertural view; 4 – side view; 5 – peripheral view; 6 – detailed view of the aperture; 7 – agglutinated texture of the test. B. *Miliammina gerochi* n.sp. – paratype; sample ZPH-2; 1 – side view; 2 – peripheral view; 3 – apertural view; 4 – detail view of the aperture. C. *Miliammina gerochi* n.sp. – paratype; sample ZPH-5; 1 – side view; 2 – peripheral view. D. *Miliammina gerochi* n.sp. – paratype; sample ZPH-5; 1 – side view; 2 – peripheral view; 3 – apertural view.
ZPH-2 and ZPH-5).

**Type-locality:** Złobowe Potoczki near Niedzica and lower part of the Upper Hyczydnian Valley (recently flooded by the Czorsztyn artificial lake), Pieniny Klippen Belt, Polish part of the Western Carpathians.

**Type-level:** Upper Hyczydnian Shale Formation; samples ZPH-1, -2, -5 (Złobowe Potoczki) and HAH-9, -10 (the Hyczydnian Valley).

**Diagnosis:** A very small, elongated spindly-shaped species of *Miliammina*, characterized by its triangular to trapezoidal cross-section and rounded periphery.

**Description:** Test free, very small, elongate, slightly flattened spindly-shaped; triangular to trapezoidal in apertural view; periphery rounded. Coiling arrangement not stable, tending to resemble quinqueloculine-like pattern (chambers one-half coil in length are successively added 144° apart creating in chambers five planes 72° apart) which is not well observed in cross-section probably due to diagenetic cementation and recrystallization of inner parts of tests (Fig. 5: E1, E2). Sutures indistinct, sometimes slightly depressed. Surface is smooth, wall very thin, finely agglutinated. Primary cement has not been recognized, most likely it was originally organic and then silicified. Aperture forms a single rounded to ovate opening at the end of the final chamber, either with or without a short neck. Better preserved apertures show a delicate rim (Fig. 4: B1-B4).

**Remarks:** Quinqueloculine arrangement is well-known from a milliards genus *Quinqueloculina*. Some species of this genus, such as *Q. agglutinans* d’Orbigny, 1839 or *Q. berthelotiana* d’Orbigny, 1839 also agglutinate fine particles (Bender, 1995). The question appears whether they should be placed into the genera *Quinqueloculina* or *Miliammina*. The absence of a calcitic millioli wall suggests closer affinity with the purely agglutinated *Miliammina* (Fig. 5: A4).

**Measurements (μm):** Holotype length = 290; max. thickness = 161; min. thickness = 148. Paratype length = 258-303; max. thickness = 148-181; min. thickness = 90-123 (figured specimens).

**Stratigraphic distribution:** Lower Bajocian.

**Deposition of types:** Coll. A-II-109, Geological Museum, Institute of Geological Sciences, Polish Academy of Sciences, Kraków.

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**REFERENCES**


**Fig. 5.** SEM photographs and microdrawings. A. *Miliammina gerochi* n.sp.; sample ZPH-2; l – side view; 2 – peripheral view; 3 – apertural view. B. *Miliammina gerochi* n.sp. – paratype; sample ZPH-5; l – side view; 2 – peripheral view. C. *Miliammina gerochi* n.sp. – paratype; sample ZPH-2; l – side view; 2 – peripheral view; 3 – apertural view. D. *Miliammina gerochi* n.sp. – paratype; sample ZPH-5; l – side view; 2 – peripheral view; 3 – apertural view. E. *Miliammina gerochi* n.sp. – paratype; sample ZPH-2; l – side view; 2 – peripheral view; 3 – apertural view.
Streszczenie

*Miliarina gerochi* n.sp. – *ŚRODKOWOJURASKA OTWORNICA (NADROZDZINA RZEHAKINACEA)*

**Jarošław Tyszyka**

Ewolucja otworów benticznych wydaje się być między innymi uzależniona od okresowego występowania warunków sielnego zubienia w tlen. Długotrwałe występowanie warunków anoksyjnych wiązane jest często ze wzmożonym wymieraniem jednych i pojawianiem się innych gatunków oraz nowych grup taksonomicznych. Warunki olimpiowe anoksyjności (subbokszczynne) sprzyjają rozwojowi szczególnych zespołów mikrofazy benticznej, zdominowanych przez gatunki olimpiowe. Przykłady takich zespółów związanych z regionalnym wydarzeniem beztlenowym na poganuclideanu i bajoszu były już wcześniej opiszane w formacji łupków ze skamieniałością z obszaru pięciolistnego pasa skałowego (Tyszyka, 1994a). Niniejsze opracowanie dotyczy dolnocambryjskiej formacji łupków z Carpathian stanowiącej w dolnej partie stratigraficznej ekwiwalent górnej części formacji łupków ze Skamieniałości (Myczynski, 1973; Birkenmajer, 1977; Fig. 1, 2). Formacja ta jest reprezentowana przez formacje czarnych łupków, której w sterydowano występowanie biofazy quasiaerańskiej, zdominowanej przez *Miliarina gerochi* n.sp., nowy gatunek aglutywujący otworów benticznych. Niniejszy gatunek jest głównym przedmiotem badań.

*M. gerochi* n.sp. jest jak dotychczas najstarszym znawanym przedstawicielem nadrodziny Rzehakinaceae. Jej występowanie jest ograniczone wyłącznie do dolnej części formacji łupków z Carpathian w pięciolistnym pasie skałkowym (Fig. 3). *M. gerochi* n.sp. tworzy od 18 do 54% zespołu współwystępuje z nosodarami, zdominowanymi przez Lenticulina spp. i Laeviddentula spp., składa się on z grubaśmi epistomidiem, astrofizydami oraz innymi otworami benticznymi. Ponadto, stosunkowo liczne są owocowce i nieorientoowane malpiażke, spikule gąbek, filamenty malza Bostira buchi, rozdziele nataomist, małe płatki oraz fragmenty szkarpliny. Zespół ten występuje w osadzie lamino- ryjnym, częściowo zaburzonym przez drobne skamieniałości sładowe złożone do innych rodzin Chlorodites. Ogólne relacje bio- fazowe wskazują, że *M. gerochi* n.sp. związana może do normalnego zasolenia, w której zewnętrznej struktury fryzowej, w warunkach eutroficznych, przy bardzo silnym zabynieniu w tlen. Na podstawie morfologii tej formy (Fig. 4, 5) oraz na podstawie badań współczesnej *Miliarina* można sugerować, że opisany gatunek preferował endobenticzny styl życia, zasiadając płytki lekko wchłaniane z warunkami subbokszczynnymi. Zespół z *M. gerochi* n.sp. wskazuje na bardzo produkcyjną fazę w historii bazu skałowego. Wsoka dostawa materii organicznej związana była z występowaniem stref mózum tlenowego, wytwarzanego poprzez cyrkulację typu "upwelllingowego". Taki typ cyrkulacji potwierdza fakt występowania równowekowych konwencji fosfo- rytowych w niewielkich płaszczyznach basenu skałowego (Tyszyka, 1995; Tyszyka & Kaminski, 1995). Stopniowy zanik *M. gerochi* oraz jej zespół należy wiązać z poprawą nawet, wzrostem gęstości zeronowania makrofaży benticznej, wzrostem temperatury, w zamiany oraz prawdopodobnie z pokątownym zasileniem basenu. Nad- legło osady górnej części formacji łupków z Carpathian charakteryzuje się lekko wchłaniana lamina te osadu oraz reprezentowane są przez zespół *Rhahamella*–*Reinholdella*–*Lenticulina*.

Porównanie różnych środowisk kolonizowanych przez rzeha- kinidy wskazuje, iż grupa ta od jury do dzisiajkolonizowała boga- te w pokarm środowiska stresowe (np. subbokszczynne, dysoksyczne lub brakiczne). Pochodzenie tej grupy i jej nowego gatunku nie zostało dotychczas wyjaśnione z powodu braku jednouczynnych przodków.