

STEFAN WITOLD ALEXANDROWICZ

Middle Miocene (Badenian) sequence at Górki, southern part of the Korytnica Bay (Holy Cross Mountains, Central Poland)

ABSTRACT: The Middle Miocene (Badenian) sequence exposed at Górki, southern part of the Korytnica Bay (Holy Cross Mountains, Central Poland), comprises sands, limestones, and marls containing a rich fossil assemblage indicative of the Lower Badenian sublittoral environments. Regional correlation of the sequence, based both upon the lithologies and foraminiferal associations, shows that two distinct Lower Badenian facies can be recognized in the Fore-Carpathian Depression. These are: sandy-calcareous-marly or clay deposits accumulated in the north, that is onshore (the Korytnica Bay including), and clayey-marly deposits accumulated in the central and southern parts of the Depression, that is offshore.

INTRODUCTION

The marine Miocene deposits filling up the Korytnica Bay are accessible in a lot of surface exposures; there is, however, no exposure showing any larger portion of the stratigraphic section in the northwestern, inner part of the Bay forming there the Korytnica basin (*vide* Radwański 1969; Bałuk & Radwański 1977, 1979). Such an exposure occurs in the outer part of the Korytnica Bay, along the railroad cut at Górki (Text-fig. 1); its first description was given by Krach (1956) and thereafter, supplemented by Alexandrowicz (1960) and Radwański (1969).

The present author investigated the Badenian sequence exposed at Górki and its microfossil assemblages in 1957—1963 when the walls of the cutting were easily accessible. Later on, the walls became gradually poorly exposed (*cf.* Text-fig. 2) and today, are entirely covered with surface slumps and plants.

SEDIMENTARY SEQUENCE

The Badenian sequence exposed at Górki overlies the erosional surface of the Kimmeridgian marly limestones (Krach 1956, Radwański 1969) and comprises the following units (*see* Text-fig. 3):



Fig. 1. Middle Miocene (Badenian) shoreline and extent of the bays on the southern slopes of the Holy Cross Mountains; preserved localities of littoral structures are marked with black spots along the shoreline (taken from: Radwański 1969, Text-fig. 25; cf. also Bałuk & Radwański 1977, Text-fig. 1C); arrowed are localities investigated and/or referenced

Within the inland areas distinguished are the occurrence zones of: 1 Cambrian (including locally Ordovician and Silurian), 2 Devonian, 3 Triassic, 4 Jurassic, 5 Cretaceous; marked with heavy dashes are the ridges in morphology that separate particular bays

1. Fine- to medium-grained limy sands with considerable amounts of calcareous grains and fragmented Jurassic flints, and abundant bivalve (mostly oyster), echinoid, and calcareous-algal detritus.

2. Lithothamnian and organodetrital limestones composed mainly of algae, foraminifers, bivalve and echinoderm detritus, with minor amounts of sandy matter.

3. Fine-grained and silty limy sands intercalated with grey, sandy marls containing ostracodes, foraminifers, and bivalve detritus.

4. Coarse-grained, poorly cemented, detrital limestones with lenses and intercalations of rather compact lithothamnian limestones.

5. Yellow-grey, sandy marls with abundant bivalves (oysters and scallops), tusk shells (*Dentalium*), bryozoans, ostracodes, and foraminifers; there are also some intercalations of medium-grained detrital limestones with rare and poorly preserved fossil remains.

6. Light-grey, marly clays and marls with a fairly abundant bivalve fauna (mostly oysters and scallops). In the upper part of this unit, there is a yellow to whitish bentonite layer of 5 cm in thickness. A mass accumulation of idiomorphic pyroclastic quartz appears in the marly clays just above the bentonite; there are well developed hexagonal bipyramids and sharp-edged transparent grains showing sometimes crystal walls with evidence for a magmatic corrosion.

7. Yellow-grey, sandy marls with a few intercalations of rather compact sandy limestones. The marls contain abundant bivalves and tusk shells associated with echinoderms, bryozoans, ostracodes, and foraminifers. A 50 cm thick bed of white bentonite occurs in the middle of the unit.

The uppermost part of the sequence consists in light-grey, marly clays found in a shallow borehole pierced at Włoszczowice (cf. Text-fig. 1), some 3 km away from the exposure at Gorki. These deposits contain abundant bivalves associated

with small-sized gastropods, echinoid spines, and benthic foraminifers dominated by *Sphaeroidina bulloides* d'Orb. They fill up the outer part of the Korytnica Bay widening there and deepening southeastwards (cf. Text-fig. 1).

FORAMINIFERAL ASSOCIATIONS

Four foraminiferal associations have been recognized in the investigated sequence, which do not appear related to any particular lithology but rather, to the habitat shift landwards during the transgression. The bathymetric interpretation is based upon the studies on ecology of the Recent foraminifers (Phleger & Parker 1951, Murray 1973, and others). The foraminiferal assemblage of Górkí is dominated by calcareous benthic forms, whereas planktic species are usually infrequent and increase in abundance exclusively in the middle of the sequence (Text-fig. 3)

AMMONIA BECCARII ASSOCIATION

This association occurs in the limy sands at the base of the sequence (unit 1 in Text-fig. 3). It comprises a few species, the most common of which are *Ammonia beccarii* (L.) and *Elphidium crispum* (L.); the two species account for 50—70% of the association, with the former one being a little more abundant. The following species occur in minor amounts: *Cibicides lobatulus* (Walk. & Jac.), *Discorbis orbicularis* (Ter.), *Gypsinia globulus* (Reuss), *Asterigerina planorbis* d'Orb.; the associated species *Amphistegina* sp., *Heterostegina costata* d'Orb., *Floridus scapha* (Ficht. & Moll) are rare.

The investigated association appears indicative of a shallow-water environment, littoral to sublittoral, not deeper than 10 m. The large amounts of the eurytopic species *A. beccarii* (L.) and

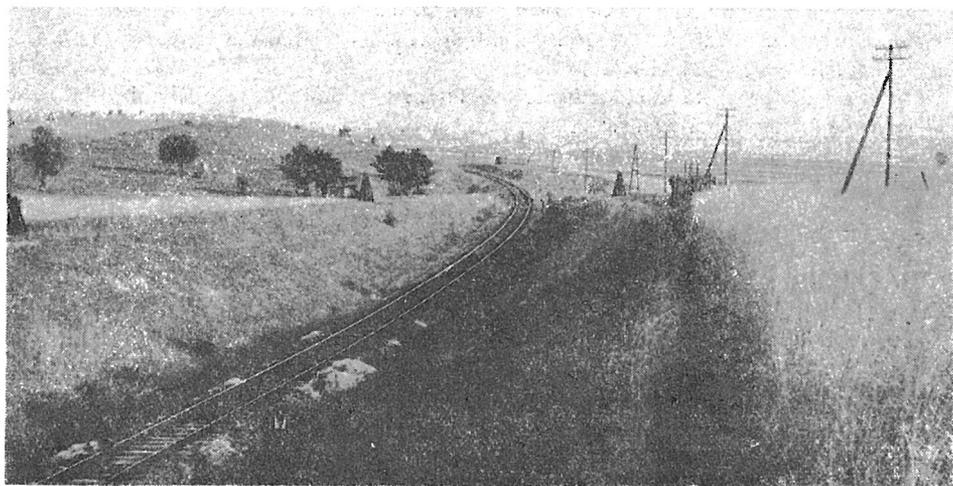


Fig. 2. Panoramic view of the railroad cut at Górkí (cf. Text-fig. 1); the state of the exposure as in 1968 (cf. Radwański 1969, Pl. 32, Fig. 1)

low species-diversity of the association may point to oligohaline conditions. Habitats suitable for settlement by foraminiferal associations of this type existed at the early stage of the Miocene transgression.

HETEROSTEGINA COSTATA ASSOCIATION

This association occurs in the detrital and sandy limestones (units 2—4 in Text-fig. 3) and comprises 14—20 benthic species, whereas planktic forms appear but sporadically. The most dominant species are: *Heterostegina costata* d'Orb., *Elphidium crispum* (L.), and *Cibicides lobatulus* (Walk. & Jac.); their proportions are variable but in general, *C. lobatulus* prevails in sands, while *H. costata* and *E. crispum* prevail in detrital limestones. These species are accompanied by *Amphistegina* sp., *Ammonia beccarii* (L.), *Asterigerina planorbis* d'Orb., *Discorbis orbicularis* (Ter.), *Loxostomum digitalis* d'Orb., *Floridus scapha* (Fichtel & Moll), and a few specimens of some other species.

The association has also been recorded in various sands, marls, and limestones of the Lower Badenian of the Miechów Upland and southern slopes of the Holy Cross Mts (Alexandrowicz 1960, 1965; Łuczowska 1964, 1967). It appears indicative of shallow-water, nearshore environments with more or less normal marine salinity. As judged from the bathymetric ranges of particular species and the occurrence of red algae, the water depth ranged from 10 to 30 m. The abundance of *Cibicides lobatulus* in the sands may indicate a flourishing of green algae providing the microhabitat for those foraminifers. The association appears indicative of the sublittoral zone of the transgressing Middle Miocene sea.

LENTICULINA ASSOCIATION

This association occurs in the marls and marly clays in the middle of the sequence (units 5 and 6 in Text-fig. 3). It is very rich in both individuals and species (over 50 species), with the smooth-tested *Lenticulina*, such as the species *L. inornata* (d'Orb.), *L. cultrata* (d'Orb.), or *L. calcar* (L.), and agglutinating forms as its most dominant components. The marly clays contain also fairly abundant *Lenticulina echinata* (d'Orb.), *L. vortex* (Fichtel & Moll), *Melonis pompilioides* (Fichtel & Moll), *Eponides omnivagus* Łucz., *Cibicides conspiciendus* Pishv., and *Hopkinsina compressa* (Cush.), while *Amphistegina* sp. occurs commonly in the marls. Planktic foraminifers make up 10 to 30% of the association and are represented mainly by *Orbulina suturalis* Bronn, *Globigerinoides trilobus* (Reuss), *G. irregularis* (Le Roy), *Globoquadrina altispira* (Cush. & Jarv.), *Globigerina bulloides* d'Orb., and *Turborotalia mayeri* (Cush. & Ell.).

The association seems to be indicative of a sublittoral to neritic zone (30—80 m in depth) especially suitable for the benthic fauna. In fact, those species typical of shallow-water habitats, present in the underlying strata, disappear gradually from the sequence. An analogous trend is also apparent in the associated mollusk fauna (cf. Krach 1956).

EPONIDES OMNIVAGUS ASSOCIATION

This association occurs in the sandy marls at the top of the exposed sequence (unit 7 in Text-fig. 3); it comprises some 30 species, the most dominant of which is *Eponides omnivagus* Łucz., accompanied mostly by *Melonis pompilioides* (Fichtel & Moll) and *Floridus scapha* (Fichtel & Moll). There are also several species recorded in the underlying marly clays, such as *Cibicides conspiciendus* Pishv., *Spiroplectamina carinata* (d'Orb.), *Uvigerina costata* Bieda, *Lenticulina cultrata* (d'Orb.), *Orbulina suturalis* Bronn, and *Globigerinoides* sp. div. Planktic forms account for less than 5% of the association. The bathymetric ranges of the dominant species point to a sublittoral to neritic zone of 30—60 m in depth.

The grey marly clays from Włoszczowice contain an entirely different foraminiferal assemblage. It comprises a dozen or so species, with *Sphaeroidina bulloides* d'Orb., *Uvigerina brunensis* Karrer, *Hoeglundina elegans* (d'Orb.), *Cibicides ungerianus* (d'Orb.) as the most abundant ones accompanied also by *Uvigerina costai* Said, *Nodosaria rudis* d'Orb., and *Bulimina striata* d'Orb. among others. Planktic forms are represented merely by a few specimens of *Globigerina bulloides* d'Orb. The association points to a neritic zone, and its low species-diversity may indicate habitat deterioration caused by changes in water salinity (cf. Łuczowska 1967).

STRATIGRAPHIC IMPLICATIONS

Stratigraphic attribution of the investigated deposits is based upon their fauna. The mollusks were identified by Krach (1956) who recognized *Chlamys latissima* (Brocchi) and *Pecten bessi* Andr. in the lower part of the sequence, and *Amussium denudatum* (Reuss), *A. cristatum* (Bronn.), *Chlamys koheni* (Fuchs), *Ch. trigonocosta* (Hilb.), *Ch. scabrella* (Lam.) in the marls and marly clays of the middle part of the

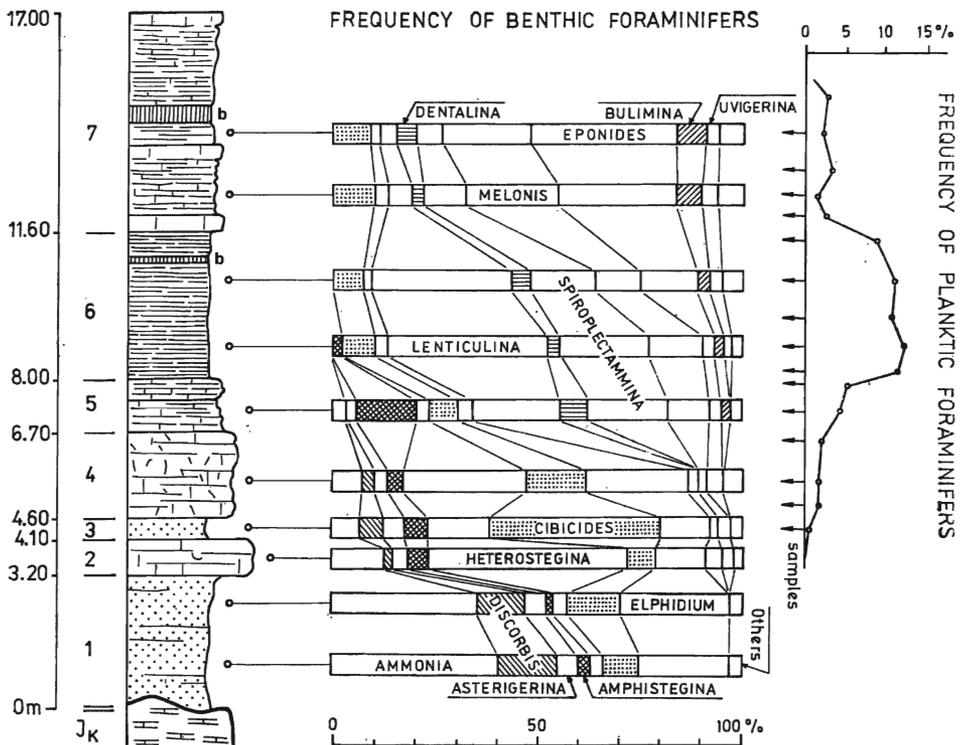


Fig. 3. Middle Miocene (Badenian) sequence exposed along the railroad at Górk within the Korytnica Bay, and frequency of foraminifers in the samples collected

1-7 — lithological units described in the text; b — bentonites; J — K [immeridgian marly limestones

sequence. In the Polish portion of the Paratethys, all these are indicative of the Lower Badenian (Opolian).

The investigated foraminiferal associations include some species characteristic of the Lower Badenian of the Polish Paratethys, associated with those of a wide stratigraphic range. The larger forms, *Heterostegina costata* d'Orb. and *Amphistegina* sp., are the most typical of the sands and detrital limestones. The planktic foraminifers, and especially *Orbulina suturalis* Bronn and *Globigerinoides trilobus* (Reuss), appear as the most noteworthy species in the marls and marly clays; among the benthic forms of this part of the section, the following species are also to be regarded as characteristic: *Lenticulina echinata* (d'Orb.), *Marginulina hirsuta* d'Orb., *Cibicides conspiciendus* Pishv., *Uvigerina costata* Bieda, *Hopkinsina compressa* (Cush.), and *Karrerella gaudryinoides* (Forn.).

The foraminiferal association recognized in the middle part of the investigated sequence (that is, the *Lenticulina* association) resembles closely those associations typical of the Badenian clayey-marly deposits of the Cracow-Silesia region and Moravia. These associations called by Grill (1941) as the "Lancendorf fauna" and by Alexandrowicz (1963) as the assemblage *IIA* are in the Polish Paratethys indicative of the Lower Badenian; by the way, they are considerably variable in composition depending upon the facies in nearshore areas (Łuczowska 1969, Alexandrowicz 1971). This fauna is clearly related to the *Orbulina suturalis* Zone of the Lower Badenian, that is to the Moravian (Cicha & al. 1975). In fact, the index species of the latter zone occurs also in the Korytnica Clays at Karsy (Janiszewska-Pactwa 1960), making part of an association rich in the nodosariids (Alexandrowicz 1960); the latter association appears also near Korytnica (Walkiewicz 1977).

The occurrence of the *Orbulina suturalis* Zone in the sequence at Górkki and in the inner part of the Korytnica Bay permits attribution of the Korytnica Clays and the overlying lithologic members of the Korytnica basin (cf. Bałuk & Radwański

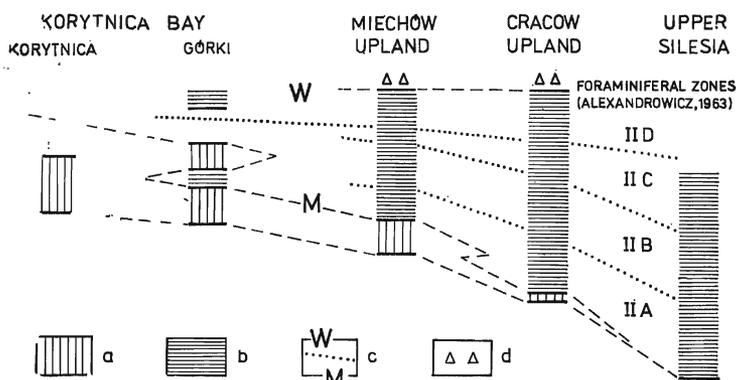


Fig. 4. Facies variability of the Lower Badenian deposits in the Polish part of the Paratethys
 a — diverse sublittoral sandy, limy/marly or clay facies (the Korytnica Clays and overlying members including; cf. Bałuk & Radwański 1977, Text-fig. 4); b — clay facies of the central and southern parts of the Fore-Carpathian Depression (the Skawina Beds); c — boundaries between the foraminiferal assemblage-range zones (*M* Moravian, *W* Wielician); d — evaporitic deposits (Gypsum member)

1977) as well as the Górki sequence to the Lower Badenian. Actually, this is a shallow-water, onshore facies (*see* Text-fig. 4) of the Skawina Beds recognized in the central and southern parts of the Fore-Carpathian Depression (Alexandrowicz 1963, 1971).

The marly clays found in the borehole at Włoszczowice contain a foraminiferal association typical of the *Uvigerina costai* Zone designated in the Cracow-Silesia region as the assemblage *IID* (Alexandrowicz 1963). This assemblage is indicative of the upper portion of the Badenian clays below the Gypsum member, equivalent to the *Spiroplectamina* Zone. Its occurrence in the southern part of the Korytnica Bay demonstrates that the onshore facies is there overlain by the Middle Badenian deposits resembling the Tegel facies. A similar succession of the Badenian foraminiferal associations has also been reported from the boreholes located south off the Holy Cross shores (Łuczowska 1964, 1967).

REMARKS ON THE BADENIAN TRANSGRESSION

The investigated sequence developed due to a marine transgression and associated habitat-shift in the basin. It starts with littoral to sublittoral deposits (sands, detritic and algal limestones) grading upwards into sediment of a somewhat deeper sea, possibly the lower sublittoral zone (marly clays, marls, and sandy marls). The gradual deepening of the basin is also reflected in changes in the foraminiferal associations (*cf.* Text-fig. 3); the shallow-water species are apparently replaced upwards with species living preferably at some tens meters in depth. This gradual change in nature of both the lithology and associated foraminiferal fauna confirms the opinion of Radwański (1969, 1973) that a single Miocene transgression did happen in the southern margin of the Holy Cross Mts.

The amounts of planktic foraminifers in the recognized associations are subordinate (a few percent), except of the marly clays (unit 6) where the planktic forms exceed 20% of the association (*cf.* Text-fig. 3). Planktic foraminifers are much more abundant in the Lower Badenian of the central part of the Fore-Carpathian Depression and in the Cracow-Silesia region where they represent up to 80% of the foraminiferal faunas (Szewczyk 1975). One may suppose that the bays formed by the Miocene transgression in the north, at the slopes of the Holy Cross Mts, were separated by some islands (*cf.* Radwański 1969) from the central part of the Fore-Carpathian Depression, which hampered migration of the planktic foraminifers. This would also explain the rarity of planktic foraminifers in the Korytnica Clays (*cf.* Alexandrowicz 1960, Janiszewska-Pactwa 1960, Walkiewicz 1977). An episode of increase in abundance of planktic foraminifers recorded in the sequence exposed at Górki corresponds to the maximum depth achieved during the development of the Korytnica Bay. Under such conditions, the *Lenticulina* association developed, resembling closely foraminiferal associations recorded in the central and southern parts of the Fore-Carpathian Depression.

The uniform nature of the Miocene transgression was recognized by Radwański (1968, 1969, 1973) both in the Miechów Upland and the Cracow-Silesia region and

along the southern and south-eastern slopes of the Holy Cross Mts. At first, a foraminiferal association dominated by planktic forms (the Lancendorf fauna) inhabited the more or less homogeneous central part of the basin. At the same time, considerably variable conditions developed onshore causing sedimentation of diverse deposits and development of diverse fossil assemblages (*cf.* Radwański 1969). Then, not only all the deposits of the Korytnica Bay but also diverse facies attributed previously to the Lower Opolian (*Heterostegina* sands, detrital and lithothamnian limestones, *Heterostegina* and *Amphistegina* marls, organogenic limestones) are to be regarded as facies equivalents of the marly clays with the Lancendorf fauna, and with *Amussium denudatum* (Reuss), and *Vaginella* sp. div. In the southern part of the Korytnica Bay, at Górkki, one may see an interfingering of the two Lower Badenian facies, which makes possible recognition of their mutual relationship (Text-fig. 4).

At the early stage of the Lower Badenian marine transgression into the Fore-Carpathian Depression, shallow-water deposits accumulated that comprise diverse fossil assemblages depending upon the local ecological conditions. This variability appears most clearly within the bays developed at the northern seashore. Seawards, the littoral to sublittoral deposits grade into the clayey-marly facies of the *Tegel* type. The fossil assemblages (especially foraminifers) typical of the latter facies increased in significance and spread with the transgression progress and the basin deepening.

At the end of the Early Badenian, just before the period of a chemical sedimentation, the Miocene facies became again uniform, which resulted in accumulation of marly clays with the foraminiferal assemblage *IID* typical of the *Uvigerina costai* Zone in a close proximity of the bays (Łuczowska 1964, 1967). Simultaneously, some non-subsiding smaller bays became then filled entirely up with sediments and hence, excluded from the later Badenian marine sedimentation (Radwański 1969, 1973).

*Institute of Geology and Mineral Deposits,
University of Mining and Metallurgy,
Al. Mickiewicza 30,
30-059 Kraków, Poland*

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