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Remarks on Miocene bivalve zonation in the Polish part of the Carpathian Foredeep

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Middle Miocene (Badenian and Sarmatian) bivalve faunas from the Carpathian Foredeep in Poland were analysed in order to determine their potential stratigraphic importance. The study revealed that selected pectinid species are useful to characterize the Badenian substages, but that comparison of pectinid assemblages from Poland and Hungary indicates that subdivision of the Badenian based on pectinids holds true only within individual basins of the Central Paratethys. On the other hand, the strong similarity of the Polish Sarmatian bivalve assemblages to assemblages from other basins of the Fore-Carpathian part as well as from the Euxino-Caspian part of the Paratethyan Province makes the molluscan biozonation of the Eastern Paratethys valid for Poland.

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Key words: Carpathian Foredeep, Middle Miocene (Badenian, Sarmatian), bivalves, biostratigraphy.

INTRODUCTION

Bivalves have lost their leading role in the stratigraphy of marine Miocene strata in favour of planktonic organisms such as foraminifers, coccolithophorids, radiolarians and diatoms. But they maintain a strong position in the stratigraphic subdivision of the deposits laid down in epicontinental basins of the Paratethys and in that of the littoral strata of the Mediterranean in which planktonic organisms are extremely poorly represented.

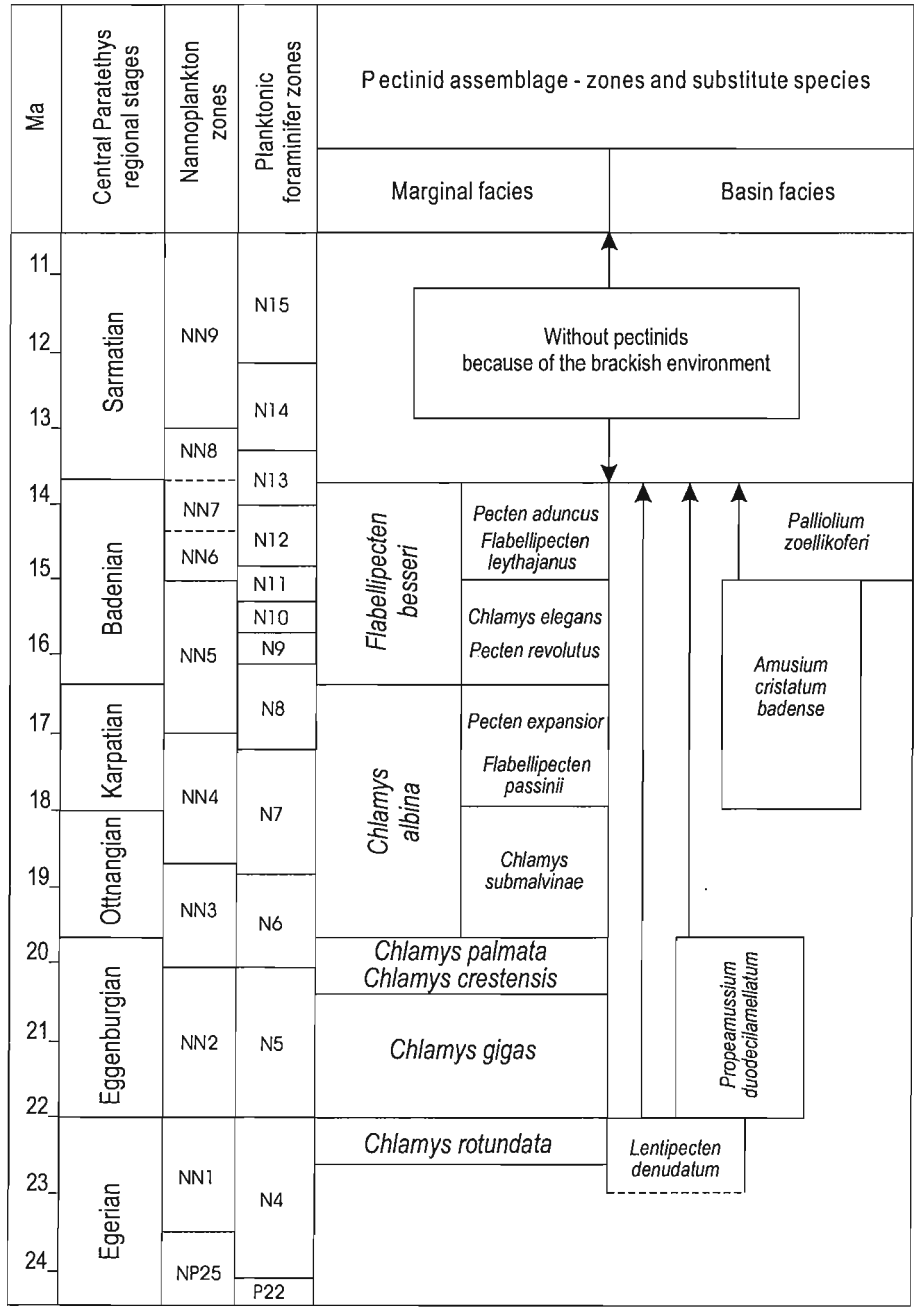
During last twenty years several schemes for subdividing the European Neogene using molluscs has been proposed (G. Demarcq, 1984; M. Dermitzakis, E. Georgiades-Dikeoulia, 1987; E. Kojumdgieva *et al.*, 1988, 1989; I. Papaianopol, M. Marunteanu, 1993). The most important biozonation was based on pectinids (T. Báldi, 1975; G. Demarcq, 1979, 1990*a, b*; M. Bohn-Havas *et al.*, 1987; A. Ben Moussa, G. Demarcq, 1992; A. Ben Moussa, 1994). This family belongs to the subclass Pteriomorphia of the class Bivalvia. Only the representatives of this subclass have calcitic shells and their preservation in various deposits is excellent. On the other hand, species representing the remaining three subclasses, i.e. Palaeotaxodonta, Heterodonta and Anomalodesmata have aragonitic shells. Preservation of aragonitic shells is very good in sandy and/or clayey facies, while the fossil assemblages from carbonate deposits are considerably impoverished due to the leaching of aragonite from the rock. As a result, the bivalves collected from carbonate deposits are mostly preserved as casts and moulds.

On the basis of thirty selected pectinid species G. Demarcq (1990*a, b*) proposed 10 biostratigraphic zones and some subzones which are valid for the Mediterranean area from the latest Oligocene (top of the Chattian) to the late Quaternary (Calabrian), covering the 27.0 to 1.8 Ma time span. However, sedimentological and biostratigraphical differences between the Mediterranean and Paratethys have led to the development of three distinct stage systems (i.e. the standard one for the Mediterranean and two regional schemes for the Central and Eastern Paratethys, respectively) and thus the molluscan biozonation proposed by G. Demarcq for the Mediterranean cannot simply be adopted for the Central Paratethys.

Studies on bivalve assemblages from the Miocene formations of Hungary revealed that the sequence extending from the Eggenburgian to the end of the Badenian can be readily characterized by the frequent occurrence of pectinids in dif-

Table 1

Pectinid assemblage zones of the Miocene in Hungary proposed by M. Bohn-Havas *et al.* (1987)



Ranking of the calcareous nannofossils after E. Martini (1971); NN4/NN5 boundary modified by M. Báldi-Becke and A. Nagymarosy (1979); ranking of the planktonic foraminiferal biohorizons after W. H. Blow (1969)

ferent facies. This part of the Miocene is made up of 37 formations forming a continuous vertical succession. These formations are very well known in a complete lateral succession of facies, from continental deposits to basin margin facies to central deep-basin facies. Isochronous, radiometrically dated markers are represented by three tuff layers which occur throughout Hungary. The age of the uppermost tuff layer separating the uppermost Badenian deposits from the lowermost Sarmatian strata has been dated by K/Ar method as 13.7±0.8 Ma (G. Hámor *et al.*, 1987). Taking into account all these data for the 23.0 to 13.8 Ma time span extending from the Eggenburgian to the end of the Badenian, the introduction of 5 pectinid assemblage zones and the distinction of 4 subzones was proposed (Tab. 1) by M. Bohn-Havas *et al.* (1987).

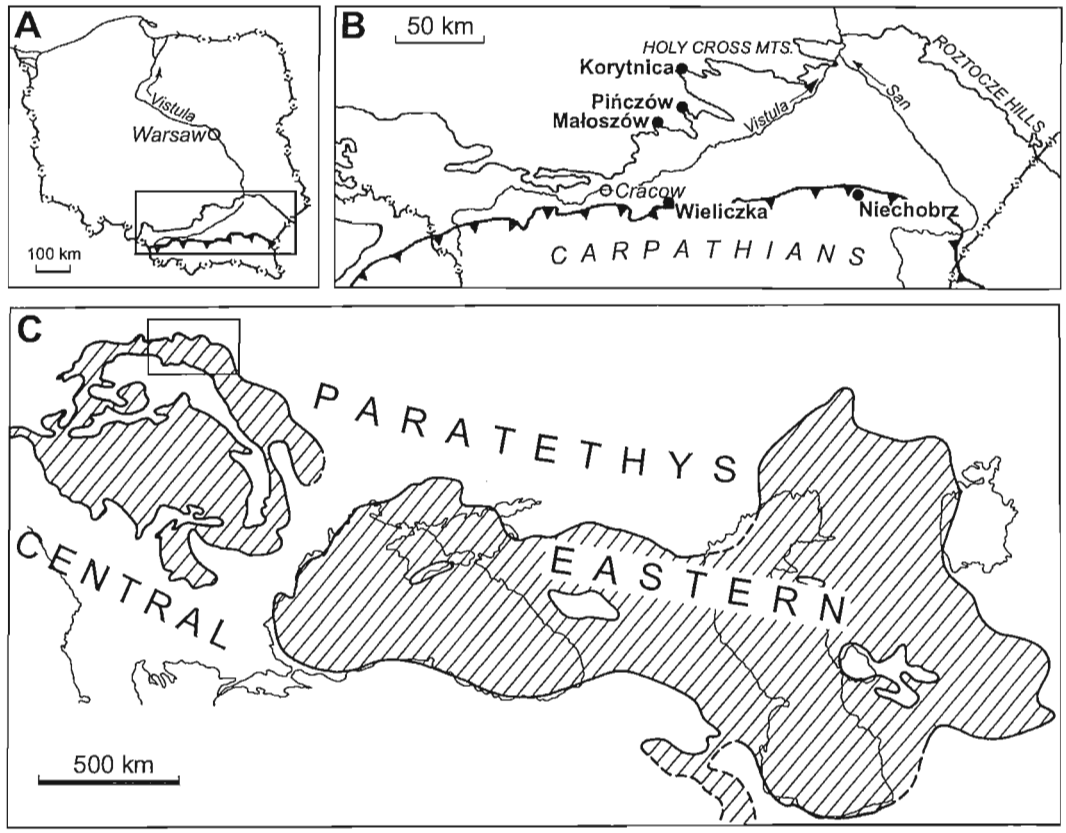


Fig. 1. Palaeogeographic location of the bivalve-bearing Early Badenian localities investigated in the Carpathian Foredeep: **A**. General location of the study area in Poland, showing the area enlarged in Fig. 1B; **B**. Extent of the Badenian sea in the Carpathian Foredeep adapted from A. Radwański (1977); **C**. Palaeogeographic setting of the Polish part of the Carpathian Foredeep in the Early Badenian — Chokrakian (age-equivalent of the Langhian) Paratethyan basins (hachured) after B. Studencka *et al.* (1998), showing the area enlarged in Fig. 1B

ANALYSIS OF THE PECTINIDS FROM POLAND

Marine strata of the outer part of the Carpathian Foredeep in Poland represent only the Middle Miocene, and only one pectinid zone corresponding to the Badenian stage, i.e. the assemblage *Flabellipecten besseri* Zone, can be recognised. Examination of bivalve faunas recorded in both Lower and Upper Badenian sandy and carbonate deposits shows the presence of 29 pectinid species (Tab. 2). These scallops came from 14 localities (Figs. 1 and 2). According to the benthic foraminiferal zonation proposed by R. Grill (1943) the bivalve assemblages from Korytnica, Małoszów, Niechobrz, and Pińczów belong to the Lagenidae Zone, whereas the assemblages from Bogucice, Gliwice Stare, Huta Różaniecka, Łychów, Monastyrz, Nawodzice, Niskowa, Rybnica, Węglin and Węglinek are referred to the *Bulimina–Bolivina* Zone.

The pectinid species composition unequivocally indicates the assemblage *Flabellipecten besseri* Zone of the Hungarian Miocene pectinid zonation. The base of this zone was originally defined (M. Bohn-Havas *et al.*, 1987) by the appearance of *Flabellipecten besseri* (Andrzejowski), *Pecten praebenedictus* (Tournouër), *Chlamys elegans* (Andrzejowski), *Chlamys flava* (du Bois) [it was synonymized by B. Studencka (1986) with *Chlamys* (*Aequipecten*) *malvinae* (du Bois)], and *Chlamys neumayri* (Hilber) [recognized by B. Studencka *et al.* (1998) to be conspecific with *Flexopecten lilli* (Pusch)] in the Hungarian Miocene basins. The appearances of all these species is linked biostratigraphically to the first appearance datum of the planktonic foraminifer of the genus *Praeorbulina*, whereas the top of this pectinid zone is defined by the disappearance of the marine molluscan fauna due to semi-marine or brackish conditions that prevailed in the Paratethyan Province, and by the appearance of palaeoenvironmentally significant species as *Abra* (*Syndosmya*) *reflexa* (Eichwald) and *Inaequicostata inopinata* (Grishkevich) (*cf.* M. Bohn-Havas, 1983). According to M. Bohn-Havas *et al.* (1987), the occurrence of *Amusium cristatum badense* Fontannes, *Lentipecten denudatum* (Reuss), *Palliolum zoellikoferi* (Bittner), and *Propeamussium duodecilamellatum* (Bronn) document the assemblage *Flabellipecten besseri* Zone in the basin facies of Hungary (Tab. 1). This zone covers a biostratigraphical interval comprising the M5, M6 and (in part) M7 zones of the planktonic foraminiferal zonation proposed by W. A. Berggren *et al.* (1995). This zone represents a Langhian to early Serravallian time span (*cf.* Tab. 3).

However, the subdivision into two subzones (Tab. 1), namely the *Chlamys elegans–Pecten revolutus* and *Flabelli-*

Table 2

Comparison of pectinid assemblages from the Badenian strata of Poland

Species \ Localities	Lower Badenian						Upper Badenian										
	Wieliczka	Małoszów	Pińczów	Korytnica	Niechobrz	Other localities	Gliwice Stare	Niskowa	Bogucice	Nawodzice	Rybnica	Węglin	Węglinek	Łychów	Monastyrz	Huta Różaniecka	Other localities
Flabellipecten besseri (Andrzejowski)		X	X		X			X	X		X					X	X
Amusium cristatum (Bronn)		X	X	X		X											
Amussiopecten spinulosus attenuatus Kojumdgieva		X	X	X		X											
Palliolum incomparabile (Risso)		X	X														
Flabellipecten solarium (Lamarck)			X		X												
Gigantopecten nodosiformis (de Serres in Pusch)		X	X	X	X	X											
Lentipecten corneus denudatus (Reuss)	X	X	X	X		X											
Hinnites brussoni (de Serres)			X														
Hinnites crispus (Brocchi)						X											
Manupecten fasciculatus (Millet)			X		X												
Mimachlamys angelonii (Stefani et Pantanelli)			X		X												
Aequipecten opercularis (Linnaeus)	X					X											
Aequipecten macrotis (Sowerby)					X												
Delectopecten similis (Laskey)				X							X				X		
Propeamussium felsineum (Foresti)						X	X								X		
Flexopecten lilli (Pusch)	X	X					X		X						X	X	X
Flexopecten posthumus (Hilber)			X		X							X			X	X	X
Flexopecten scissus (Favre)			X				X		X	X	X				X	X	X
Pecten subarcuatus Tournouër			X								X		X				
Oppenheimopecten aduncus (Eichwald)			X	X		X		X	X					X			
Oppenheimopecten revolutus (Michelotti)		X	X	X				X					X				
Crassadoma multistriata (Poli)		X	X		X		X	X	X			X	X	X		X	X
Aequipecten scabrellus (Lamarck)	X	X	X	X	X	X	X			X	X				X	X	X
Delectopecten vitreus (Gmelin)											X				X		
Palliolum bittneri (Toula) [= *Palliolum elini* (Zhizhchenko)]							X										X
Aequipecten diaphanus (du Bois)																	X
Aequipecten elegans (Andrzejowski)							X		X			X	X	X		X	X
Aequipecten malvinae (du Bois)										X	X					X	
Aequipecten radians (Nyst)											X						

Data after W. Bałuk (1970), W. Friedberg (1932, 1933, 1936), G. Jakubowski, T. Musiał (1979*a, b*), W. Krach (1947, 1957, 1981), K. Kowalewski (1930), S. Liszka (1933), B. Studencka (1986, 1994) and B. Studencka and W. Studencki (1988); the systematic arrangement of scallops applied here follows T. R. Waller (1991)

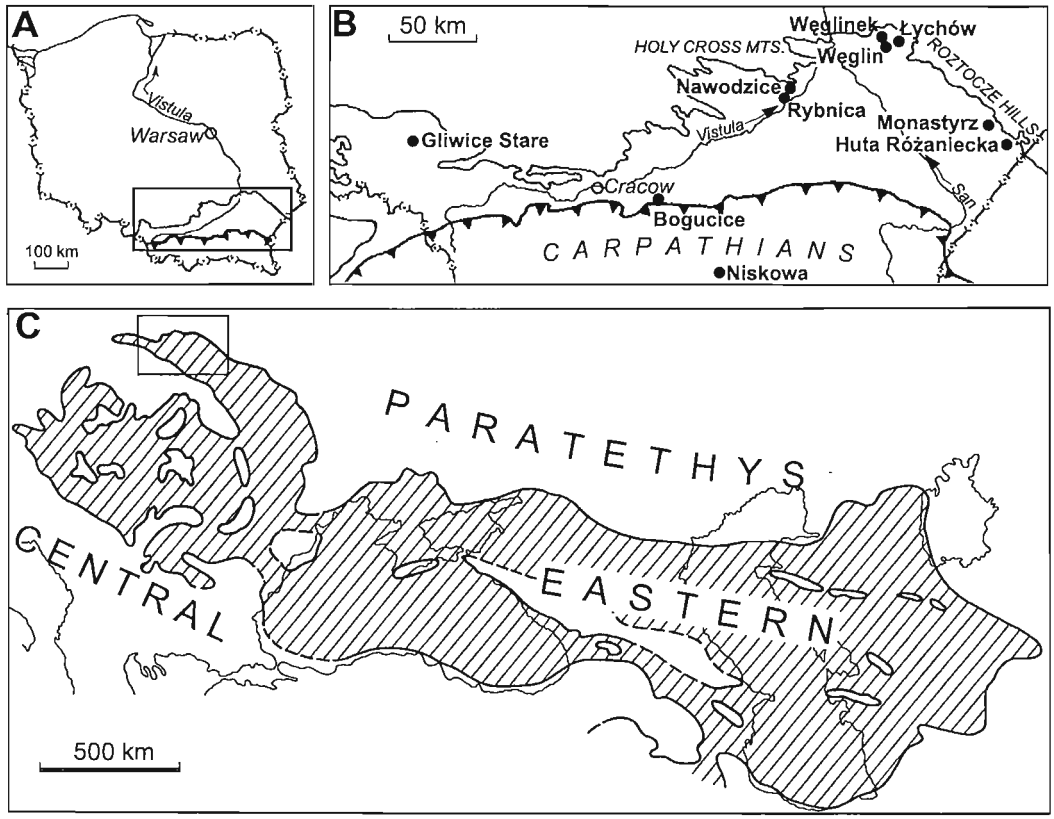


Fig. 2. Palaeogeographic location of the bivalve-bearing Late Badenian localities investigated in the Carpathian Foredeep: A. General location of the study area in Poland, showing the area enlarged in Fig. 2B; B. Extent of the Badenian sea in the Carpathian Foredeep adapted from A. Radwański (1977); C. Palaeogeographic setting of the Polish part of the Carpathian Foredeep in the Late Badenian — Konkian (age-equivalent of the early Serravallian) Paratethyan basins (hachured) after B. Studencka *et al.* (1998), showing the area enlarged in Fig. 2B

pecten leythajanus–Pecten aduncus subzones proposed for the Badenian of Hungary by M. Bohn-Havas *et al.* (1987) is not valid for the Carpathian Foredeep. This results from the diachronous appearance of some index species of these two subzones and from the occurrence of other species limited to particular basins of the Central Paratethys. The main differences between the pectinid assemblages concern the species *Aequipecten elegans* (Andrzejowski) and *Flabellipecten leythajanus* (Partsch in Hörnes).

The occurrence of the species *Aequipecten elegans* in the Central Paratethys appears to be diachronous. This species is typical of the Lower Badenian carbonate and sandy facies of Hungary (I. Csepreghy-Meznerics, 1960; M. Bohn-Havas *et al.*, 1987; A. Dulai, 1996). It has also been reported from the Lower Badenian of Romania (E. Nicorici, 1977). On the other hand, the specimens of *Aequipecten elegans* are, along with *Flexopecten scissus* (Favre), among the most common pectinid representatives in the Upper Badenian deposits of Romania, Slovakia, and along the Roztocze Hills and northern Carpathian margin in Poland (E. Nicorici, 1977; J. Švagrovsky, 1981*a, b*; G. Jakubowski, T. Musiał, 1979*a, b*; J. Urbaniak, 1974; respectively).

Specimens of *Flabellipecten leythajanus* are common and typical fossils in the Middle and Upper Badenian carbonate facies of Austria and Hungary (F. Kautsky, 1928; R. Sieber, 1955; I. Csepreghy-Meznerics, 1960; M. Bohn-Havas *et al.*, 1987), and in the Upper Badenian carbonate facies of Slovakia (J. Švagrovsky, 1981*b*). In the Transylvanian, the Banat, and the western Dacian basins in Romania, however, *Flabellipecten leythajanus* occurs in both the Lower and the Upper Badenian. According to E. Nicorici (1977), this species is one of the most abundant fossils in the Upper Badenian, along with *Flabellipecten besseri* (Andrzejowski), *Oppenheimopecten aduncus* (Eichwald), *Aequipecten elegans* (Andrzejowski) and *Gigantopecten nodosiformis* (de Serres in Pusch). All these findings of *Flabellipecten leythajanus* are located in the Intra-Carpathian basins of the Central Paratethys. On the other hand, the species *Flabellipecten leythajanus* has not been found in the Fore-Carpathian part of the Central Paratethys, in spite of the presence of a well-developed carbonate facies in Romanian Moldavia (E. Nicorici, 1977), Moldova (M. I. Voloshina, 1973; A. N. Yanakevich, 1977, 1993), the Ukraine (W. P. Kazakova, 1952), and in Poland (G. Jakubowski, T. Musiał, 1979*a, b*; W. Krach, 1981). This suggests that the geographic distribution of *Flabellipecten leythajanus* — the index species of the Badenian *Flabellipecten leythajanus–Pecten aduncus* Subzone — is limited to the Inner-Carpathian basins.

Of the remaining two index species, *Oppenheimopecten revolutus* (Michelotti) is rare in the Lower Badenian of Poland, while *Oppenheimopecten aduncus* is extremely rare in the Upper Badenian. Six specimens of *Oppenheimopecten revolutus* were recorded in the limestones near Małoszów (W. Krach, 1947), 8 specimens have been also reported from the carbonate deposits of the Wójcza–Pińczów Range (W. Friedberg, 1936; B. Studencka, W. Studencki, 1988) and a single specimen from the Korytnica Clay (W. Friedberg, 1936). Only one specimen of *Oppenheimopecten aduncus* was recorded in Łychów (W. Krach, 1981) and Bogucice (W. Friedberg, 1936) and 4 specimens in Niskowa (W. Bałuk, 1970).

A further difference between the pectinid assemblages from the Inner- and Fore-Carpathian basins concerns the species *Flexopecten scissus*. Its occurrence in the Central Paratethys is also diachronous. The oldest findings are documented from few Lower Badenian localities in Bulgaria (E. Kojumdgieva, 1960), the Ukraine (W. P. Kazakova, 1952), and Poland (W. Friedberg, 1932, 1936; W. Krach, 1957, 1967, 1979; B. Studencka, W. Studencki, 1988). Specimens of *Flexopecten scissus* are very common in the Upper Badenian deposits of Poland (G. Jakubowski, T. Musiał, 1979*a, b*; W. Krach, 1957, 1967, 1979; E. Woźny, 1962) the Ukraine (W. Friedberg, 1932, 1936; V. Hilber, 1882*a, b*; W. P. Kazakova, 1952), Romanian Moldavia (B. Ionesi, 1968; E. Nicorici, 1977) and Bulgaria (E. Kojumdgieva, 1960, 1969*b*). In contrast, this species is extremely poorly represented in the Upper Badenian of Hungary (I. Csepreghy-Meznerics, 1960) and Slovakia (J. Švagrovsky, 1981*b*). There are apparently no records of the *Flexopecten* group in the Badenian of Austria (F. Kautsky, 1928; R. Sieber, 1955).

Close inspection of bivalve faunas from both the Lagenidae and *Bulimina–Bolivina* zones in Poland reveals some modification in pectinid species composition in time. Of 29 species recorded in the Badenian of Poland, the occurrence of 11 species in the Carpathian Foredeep is restricted to the Lagenidae Zone (i.e. lower part of the assemblage *Flabellipecten besseri* Zone). This group includes *Palliolum incomparabile* (Risso), *Amusium cristatum* (Bronn), *Amussiopecten spinulosus attenuatus* Kojumdgieva, *Gigantopecten nodosiformis* (de Serres in Pusch), *Lentipecten corneus denudatus* (Reuss) and *Manupecten fasciculatus* (Millet).

On the other hand, the upper part of the assemblage *Flabellipecten besseri* Zone in the Polish part of the outer foredeep is characterized by a co-occurrence of *Flexopecten lilli* (Pusch), *F. scissus* (Favre), *Aequipecten elegans* (Andrzejowski), *A. malvinae* (du Bois) and *A. scabrellus* (Lamarck). Earlier analysis clearly shows that the specific composition of the pectinid assemblages depended also on water depth and hydrodynamic regime (*cf.* B. Studencka, 1994). The pectinid assemblages from Węglin, Węglinek and Łychów (western part of the Roztocze Hills) are strongly dominated by the shallow-water, reef-dwelling species *Crassadoma multistriata* (Poli), with occasional *Aequipecten elegans* and extremely rare valves of other species, whereas in the assemblages from Monastyrz and Huta Różaniecka (eastern part of the Roztocze Hills) the most common species are *Flexopecten scissus* and *Aequipecten elegans*, both typical of deeper bottoms, distant from the shore.

The impoverishment of fauna observed in the uppermost part of this zone is expressed by the decreased number of species. In several profiles the pectinid fauna consists merely of the single species *Palliolum bittneri* (Toula) [= *Palliolum elini* (Zhizhchenko)]. It is remarkable that this species, apart from being recorded in the uppermost Badenian deposits of Bulgaria (E. Kojumdgieva, 1969*b*), the Ukraine (W. P. Kazakova, 1952) and Poland (K. Kowalewski, 1958; E. Woźny, 1962; W. Krach, 1979; S. Pawłowski *et al.*, 1985) occurs also in the uppermost Konkian strata of the Precaucasus (W. P. Kazakova, 1952; L. A. Nevesskaja *et al.*, 1993) of the Eastern Paratethys.

CHANGES AROUND THE BADENIAN/SARMATIAN BOUNDARY

The Badenian/Sarmatian boundary corresponds with a drastically reduced diversity of the bivalve faunas. The marine fauna has been strongly influenced by the closure of the Mediterranean seaways in the Central and Eastern Paratethys. In both parts of the Paratethys significant faunal impoverishment is documented. The number of families decreases from 59 recognized in the Upper Badenian of the Central Paratethys and from 28 in the Konkian of the Eastern Paratethys to 12 in both parts of the Paratethys. The Sarmatian fauna populating the Paratethyan Province is represented only by the following families: Mytilidae, Ostreidae (a single species occurs in the Pannonian and Precarpathian basins), Lucinidae, Cardiidae, Mactriidae, Mesodesmatidae, Solenide, Tellinidae, Semelidae, Donacidae, Veneridae and Pholadidae but only the families Cardiidae, Mactriidae, Donacidae and Veneridae reached their highest development (*cf.* E. Kojumdgieva 1969*a*; J. Kókay, 1985; A. Papp, 1974; N. P. Paramonova, 1985, 1994; L. A. Nevesskaja *et al.*, 1986; B. Studencka *et al.*, 1998). It is remarkable that the bivalve fauna from both the uppermost Badenian and upper Konkian strata consists predominantly of species known to be only subordinate elements in both Early and Late Badenian faunas as well as in the Konkian fauna. The majority of these opportunistic bivalve species were immediate ancestral forms of Sarmatian species. According to B. Studencka *et al.* (1998), the original area for the species *Obsoletiforma obsoleta* (Eichwald), *O. kokkupica* (Andrussow), *Cerastoderma praeplicata* (Hilber) and *Mactra* (*Sarmatimactra*) *eichwaldi* Laskarew, which flourished in Early Sarmatian time, was the Central Paratethys.

The study of the Badenian and Sarmatian faunas from Poland revealed that out of 204 species recorded in the Badenian sandy and carbonate deposits in Poland (B. Studencka, 1986, 1994; B. Studencka, W. Studencki, 1988; B. Studencka *et al.*, 1998), only 20 species are also reported from the Lower Sarmatian (*cf.* B. Studencka, W. Studencki, 1980; G. Czapowski, B. Studencka, 1990), but pectinids are missing among them.

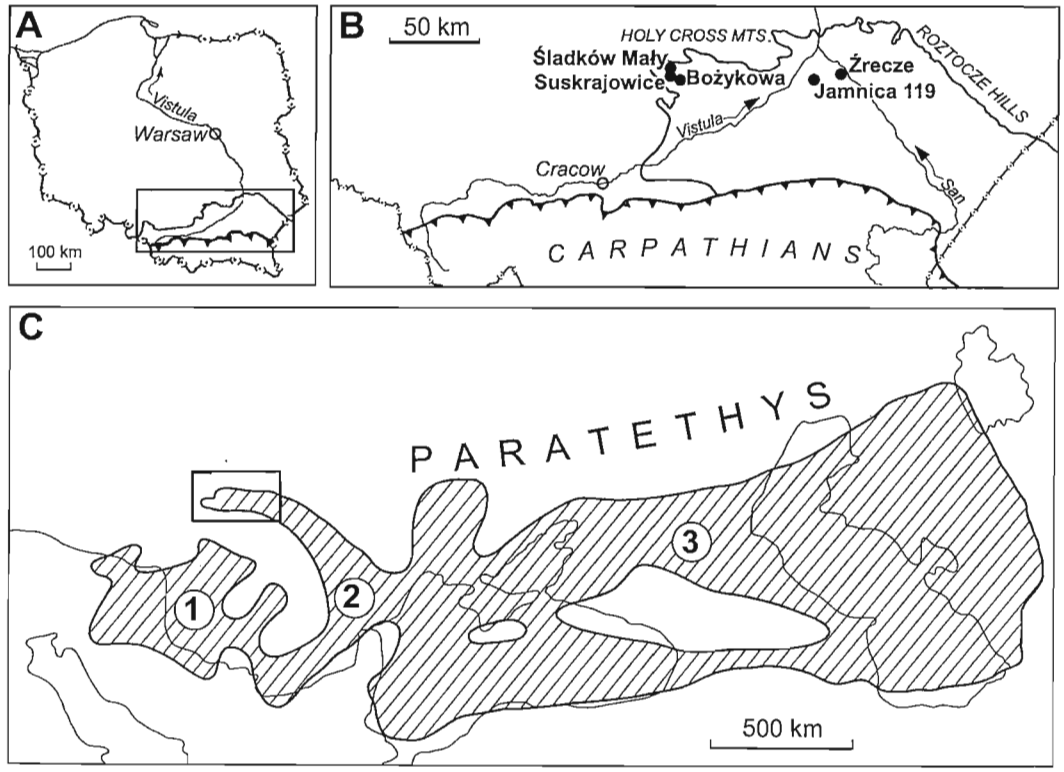


Fig. 3. Palaeogeographic location of the bivalve-bearing Sarmatian localities investigated in the Carpathian Foredeep: **A**. General location of the study area in Poland, showing the area enlarged in Fig. 3B; **B**. Extent of the Sarmatian strata in the Carpathian Foredeep adapted from R. Ney *et al.* (1974); **C**. Palaeogeographic setting of the Polish part of the Carpathian Foredeep in the Early Sarmatian (age-equivalent of the middle Serravallian) Paratethyan basins (hachured) after E. Kojumdgieva (1987), showing the area enlarged in Fig. 3B

1 — Vienna–Pannonian Basin, 2 — Fore-Carpathian Basin, 3 — Euxino-Caspian Basin

SARMATIAN BIVALVE ASSEMBLAGES

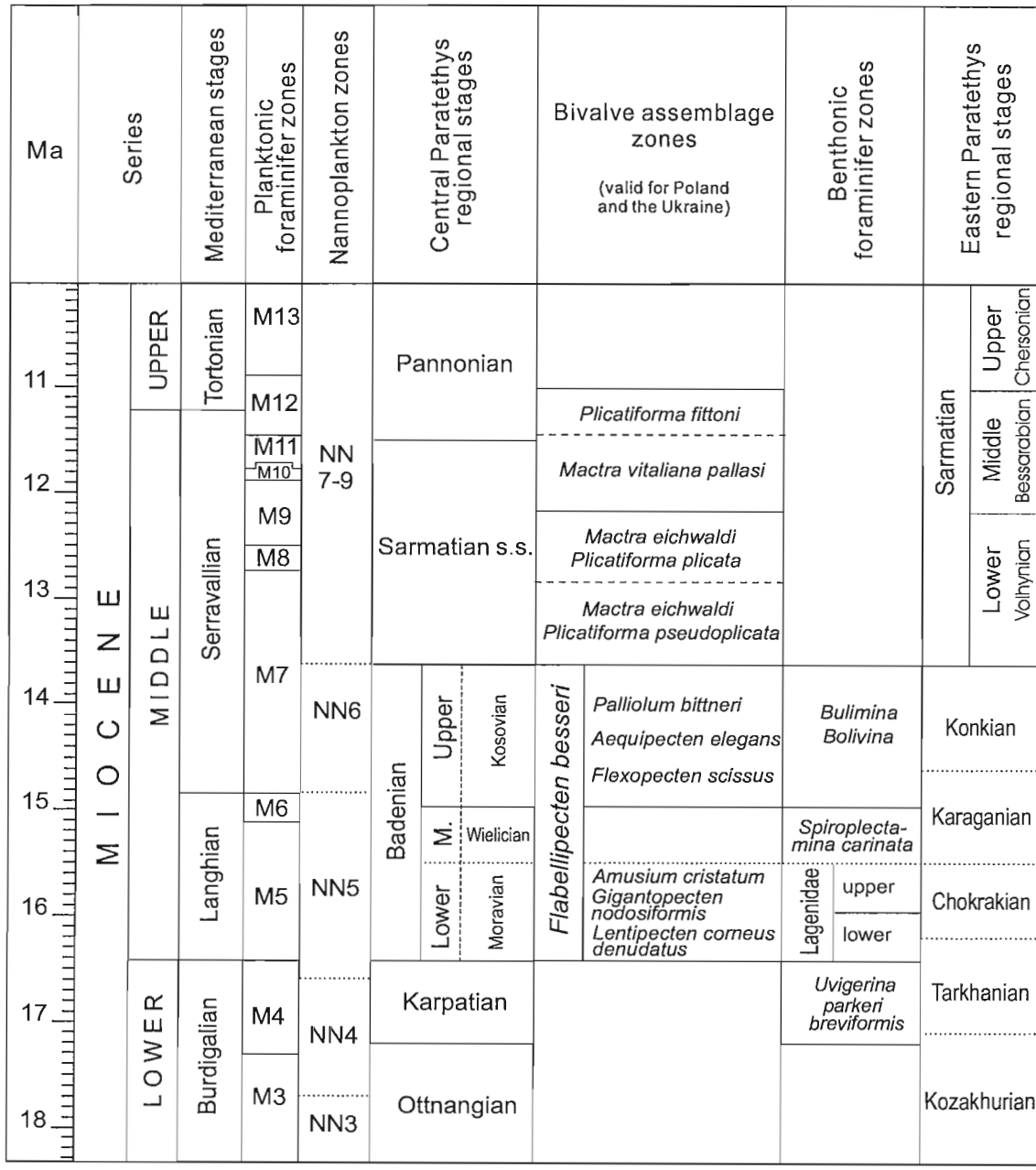
Various studies carried out on Sarmatian bivalve assemblages from the Paratethyan Province (E. Kojumdgieva, 1969*a*, 1987; L. B. Iljina *et al.*, 1976; N. P. Paramonova 1985, 1994, 1995; L. A. Nevesskaja *et al.*, 1986; E. Kojumdgieva, N. Popov, 1987; E. Kojumdgieva *et al.*, 1988; B. Studencka, 1990) revealed that the endemic forms of latest Badenian and Konkian faunas, reached their highest development in the Early Sarmatian (*sensu* Barbot de Marny). According to E. Kojumdgieva *et al.* (1988, 1989), it is possible to subdivide the Sarmatian stage, covering 13.6 to 9.5 Ma time span, using the following bivalve genera: *Ervilia* Turton, *Abra* (*Syndosmya*) Recluz, *Mactra* (*Sarmatimactra*) Korobkov, *Cryptomactra* Andrussow, *Plicatiforma* Paramonova and *Chartocardium* Muskhelishvili in Bagdasarjan. Three Sarmatian substages, i.e. Volhynian, Bessarabian and Chersonian, can be characterized by distinct bivalve assemblages. However, ecological differences between the marginal and basin facies resulted in the development of two distinct biozonal sequences: one for sandstones and detrital limestones and the second for pelitic sediments. The correlation between the two biozonal sequences is approximate. The Volhynian substage is subdivided into two concurrent-range zones: the lower of *Mactra eichwaldi–Plicatiforma praeplicata pseudoplicata* and the upper of *Mactra eichwaldi–Plicatiforma plicata*. On the other hand, the occurrence of *Abra* (*Syndosmya*) *reflexa* (Eichwald) indicates the Volhynian in pelitic sediments, whereas the stratigraphically significant species *Chartocardium nigrum* (Zhizhchenko) is limited to the upper part of the Volhynian substage. According to the biostratigraphical zonation based on foraminifera, the *Mactra eichwaldi–Plicatiforma praeplicata pseudoplicata* Zone coincides with the *Anomalinoides badensis* Zone, whereas the *Mactra eichwaldi–Plicatiforma plicata* Zone corresponds to the *Elphidium hauerinum* and the lower part of the *Protelphidium subgranosum* zones (E. I. Kojumdgieva *et al.*, 1988).

The Polish Sarmatian bivalve fauna analysed was collected from 3 localities (Bożykowa, Suskrajowice and Śladków Mały) located on the southern slopes of the Holy Cross Mts., from Źrecze near Nisko, and from the Jamnica S-119 borehole.

B. Studencka and W. Studencki (1980) considered that the variable conditions of sedimentation of the Lower Sarmatian led to the development of short-lived biocenoses, dominated by opportunistic species. Their taxonomic composition (see G. Czapowski, B. Studencka, 1990) does not significantly differ from the Ukrainian, Romanian and Bulgarian assem-

Table 3

Correlation chart of Middle Miocene regional stages of the Central and Eastern Paratethys and Mediterranean Tethys modified after B. Studencka *et al.* (1998)



Chronology of the Mediterranean stages after W. A. Berggren *et al.* (1995); radiometric age of the stages and substage boundaries of the Central Paratethys after D. Vass *et al.* (1987); bivalve assemblage zones of the Sarmatian after E. Kojumdgieva *et al.* (1988)

blages (L. B. Iljina *et al.*, 1976; I. Papaionopol, M. Marunteanu, 1993; E. Kojumdgieva *et al.*, 1989; respectively) and can be directly correlated with the concurrent-range *Mactra eichwaldi–Plicatiforma praeplicata pseudoplicata* Zone proposed by E. I. Kojumdgieva *et al.* (1988). The dominant species in all the bivalve assemblages studied from the southern slopes of the Holy Cross Mts. is *Ervilia podolica* (Eichwald), known to be only a subordinate element in Late Badenian assemblages. Another common bivalve species is *Loripes* (*Loripes*) *dujardini* (Deshayes), in which, some localities, e.g. in Śladków Mały or in Zaleśce in the Ukraine, is almost equal in numbers with *Ervilia podolica*. Study of

calcareous nannofossils from Romania by I. Papaianopol and M. Marunteanu (1993) shows that the time interval of the *Mactra eichwaldi–Plicatiforma praeplicata pseudoplicata* Zone is covered by the NN7 standard nannozone, and in the Dacian Basin the Badenian/Sarmatian boundary corresponds to the NN6/NN7 zonal boundary.

On the other hand, the most abundant species in assemblages from the lower part of the Sarmatian sequence (occurring at a depth of 229.2–240.0 m) in the Jamnica S-119 borehole is *Abra* (*Syndosmya*) *reflexa*. Also common is the typical Sarmatian representative of the family Cardiidae, namely *Inaequicostata inopinata* (Grishkevich). Its stratigraphic range is limited to the Volhynian substage (E. Kojumdgieva, 1987; L. A. Nevesskaja *et al.*, 1993; N. P. Paramonova, 1994). The taxonomic composition of these assemblages very closely resembles the one reported by M. Bohn-Havas (1983) from the clay-marls and siltstones of the Budajenö 2 borehole (occurring at the depth range 296.6–334.0 m) in the Pannonian Basin.

The bivalve assemblage recorded in the sandy facies in Źrecze near Nisko represents the *Mactra eichwaldi–Plicatiforma plicata* Zone which corresponds to the Upper Volhynian.

The biostratigraphically youngest bivalve fauna found in the Carpathian Foredeep in Poland, containing *Plicatiforma plicatofittoni* (Sinzov), *Obsoletiforma volhynica* (Grishkevich) and *Mactra* (*Sarmatimactra*) *andrussovi* Kolesnikow, was recorded in the upper part of the Sarmatian sequence in the Jamnica S-119 borehole (occurring at the depth range 65.0–67.5 m). Unfortunately, the index species of both the concurrent-range *Mactra eichwaldi–Plicatiforma plicata* Zone and the interval *Mactra vitaliana pallasi* Zone, and other representatives of the genus *Cryptomactra* Andrussow are missing in analysed assemblage. With the occurrence of *Plicatiforma plicatofittoni*, *Obsoletiforma volhynica* and *Mactra* (*Sarmatimactra*) *andrussovi* it is only possible to define the age of these strata as uppermost *Mactra eichwaldi–Plicatiforma plicata* Zone or lowermost *Mactra vitaliana pallasi* Zone which corresponds to the Volhynian/Bessarabian boundary.

CONCLUSIONS

1. Investigation of pectinids has revealed that only the assemblage *Flabellipecten besseri* Zone occurs within the Miocene marine deposits in Poland.

2. Studies of pectinid assemblages from the Paratethyan Province show no species to appear isochronously over this province. As a consequence, the subdivision of the Badenian stage based on pectinids is possible only within individual basins of this province.

3. The species *Gigantopecten nodossiformis*, *Amusium cristatum*, *Lentipecten corneus denudatus*, and *Aequipecten elegans*, *Flexopecten scissus* and *Palliolum bittneri* used to be considered significant in stratigraphic subdivision of the Lower versus Upper Badenian (respectively) littoral deposits of Poland and the West Ukraine.

4. The appearance of *Palliolum bittneri* in the Paratethyan Province is recognized as a distinct marker for reliable correlation of the top of the Badenian and Konkian stages.

5. Three bivalve zones are recognized in the Sarmatian detrital deposits of Poland viz., the concurrent-range *Mactra eichwaldi–Plicatiforma praeplicata pseudoplicata* Zone (equivalent to the lower part of the Volhynian substage), the concurrent-range *Mactra eichwaldi–Plicatiforma plicata* Zone (equivalent to the upper part of the Volhynian substage) and the interval *Mactra vitaliana pallasi* Zone (equivalent to the lower part of the Bessarabian substage).

6. Only the interval *Abra reflexa* Zone, equivalent to the Volhynian substage, was found in the Sarmatian pelitic sediments of the Carpathian Foredeep in Poland.

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O BADEŃSKICH I SARMACKICH ZESPOŁACH MAŁŻOWYCH ZAPADLISKA PRZEDKARPACKIEGO

Streszczenie

Małże, mimo iż swą wiodącą rolę w stratygrafii miocenu utraciły na rzecz organizmów planktonicznych, wciąż są niezwykle ważne w rozpoziomowaniu osadów powstałych w epikontynentalnych basenach Paratetydy.

Przedyskutowano rolę zespołów małżowych w charakteryzowaniu poszczególnych podpięter badenu i sarmatu. Badaniom porównawczym poddano zespoły przegrzebków pochodzące z 5 stanowisk dolnego badenu (fig. 1) i 10 stanowisk górnego badenu (fig. 2) oraz zespoły małżowe z 5 stanowisk sarmatu (fig. 3) polskiej części zapadliska przedkarpackiego.

Spośród 5 poziomów zespołów przegrzebków wyróżnionych w osadach miocenu Węgier (tab. 1) został stwierdzony tylko poziom *Flabellipecten besseri*. Diachroniczne pojawiawnie się przegrzebków i ich ograniczone rozprzestrzenienie wewnątrz Paratetydy Środkowej uniemożliwia wydzielenie w obrębie polskiego badenu dwóch podpoziomów: *Pecten revolutus–Chlamys elegans* i *Pecten aduncus–Flabellipecten leythajanus*, proponowanych dla badenu Węgier. Zespół przegrzebków z badenu Polski obejmuje 29 gatunków (tab. 2); występowanie 11 gatunków ograniczone jest do dolnego badenu. Dla górnego badenu gatunkami charakterystycznymi są: *Aequipecten malvinae*, *Aequipecten elegans*, *Flexopecten lilli* i *Flexopecten scissus*. Gatunki z rodzaju *Flexopecten* wraz z *Palliolum bittneri* datują najwyższy baden facji basenowej.

Datowanie klastycznych osadów sarmatu możliwe jest natomiast dzięki obecności w analizowanych zespołach małżowych gatunków z rodzaju *Plicatiforma*. W stratygraficznym podziale sarmatu proponowanym przez E. Kojumdżiewą i in. (1988) w sarmacie dolnym (wołynie) wyróżniono dwa poziomy współwystępowania: dolny *Mactra eichwaldi–Plicatiforma praeplicata pseudoplicata* i górny *Mactra eichwaldi–Plicatiforma plicata* (tab. 3). Skład taksonomiczny zespołów z Bożykowej, Suskrajowic i Śladkowa Małego jest typowy dla poziomu dolnego, podczas gdy obecność gatunku indeksowego *Plicatiforma plicata* w zepole ze Źrecza jednoznacznie wskazuje na poziom górny. Najmłodsze osady sarmackie datowane na późny wołyn/wczesny bessarab pochodzą z otworu wiertniczego Jamnica S-119 (głęb. 65,0–67,5 m). Brak gatunków indeksowych uniemożliwia dokładne podanie poziomu.