

The bivalve faunas as a basis for reconstruction of the Middle Miocene history of the Paratethys

BARBARA STUDENCKA¹, IRINA A. GONTSHAROVA² & SERGEY V. POPOV²

¹ Muzeum Ziemi, Polska Akademia Nauk, Aleja Na Skarpie 20/26, 00-488 Warszawa, Poland

² Palaeontological Institute, Russian Academy of Sciences, Profsoyuznaja Street 123, 117 647 Moscow, Russia

ABSTRACT:

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The paper deals with the Paratethyan bivalve fauna recorded in Middle Miocene marine shallow-water sandy facies. Of the 429 recognized species, 343 occur in the Lower Badenian, 71 in the Chokrakian, 316 in the Upper Badenian, and 97 in the Konkian. Bivalve faunas are analyzed in order to determine the degree of similarity of contemporaneous assemblages from the Central and Eastern Paratethys, as well as from Mediterranean and Atlantic bioprovinces.

The study of Lower Badenian and Chokrakian bivalve faunas (isochronous with the Langhian fauna of the Mediterranean) reveals that the Eastern Paratethys was cut off intermittently from communication with the Central Paratethys. Biogeographic affinities and the geographic pattern of Chokrakian bivalve assemblages indicates that the south-eastern part of the Eastern Paratethys was connected with the world ocean by a passage towards the East Mediterranean named the Middle Araks Straight. The species composition of Lower Badenian bivalve assemblages indicates a wide connection between the Central Paratethys and the Mediterranean. Apart from the western passage named the Transtethyan Trench Corridor, the East Mediterranean connection is postulated.

Comparison of the species composition of Konkian and Upper Badenian bivalve assemblages (isochronous with the lower Serravallian assemblages of the Mediterranean) suggests active faunal interchange between the Eastern and Central Paratethys. The distributional pattern of the Konkian bivalve fauna also indicates a seaway connection towards the East Mediterranean through the re-opened Middle Araks Straight. The strong similarity between the Upper Badenian fauna from the Central Paratethys and the Middle Miocene fauna of the Mediterranean and Atlantic bioprovinces shows the existence of open marine connection and faunal interchange despite the closure of the Transtethyan Trench Corridor.

Contents

INTRODUCTION	286	PROVENANCES	288
MATERIAL	287	Lower Badenian of the Central Paratethys	288
		Chokrakian of the Eastern Paratethys	289

Upper Badenian of the Central Paratethys	289	Towards East Mediterranean	325
Konkian of the Eastern Paratethys	290	Eastern Paratethys	326
CHECKLIST OF PARATETHYAN BIVALVE SPECIES	290	Disconnection of the Central and Eastern Paratethys	328
TAXONOMIC REMARKS	291	EARLY SERRAVALLIAN	
PROBLEMS CONCERNING THE CORRELATION OF THE TARKHANIAN	320	MEDITERRANEAN TETHYS – PARATETHYS CONNECTIONS	329
LANGHIAN MEDITERRANEAN TETHYS – PARATETHYS CONNECTIONS	324	Central Paratethys	329
Central Paratethys	324	Eastern Paratethys	330
		Origin of the Sarmatian fauna	332
		Acknowledgements	332
		REFERENCES	333

INTRODUCTION

The Miocene bivalves, a subject of numerous classic palaeontological monographic studies, have attracted the attention of researchers for over 150 years. The excellent preservation state of fossil forms as well as the presence in Miocene fossil assemblages of species still living in Recent seas or of species closely related to them (which involves good knowledge of their autoecology), make the bivalves a group of organisms of major importance for zoo- and palaeogeographical reconstructions. Although bivalves have lost their leading role in the stratigraphy of marine Miocene strata in favour of planktonic organisms such as foraminifers, coccoliths, radiolarians and diatoms, they still retain a strong position in stratigraphic subdivision of the deposits laid down in epicontinental basins of the Paratethys, as well as in palaeogeographic reconstructions. However, their role in both areas has been limited because of an inappropriate approach to species concept in the past.

The bivalve faunas of the European Miocene belong, according to RÖGL & STEININGER (1984), to three bioprovinces: Atlantic-Boreal; Mediterranean (or Tethyan); and the Trans-European province of the Paratethys. Palaeontological studies which started in 19th century were undertaken almost simultaneously and independently in all three bioprovinces. Because of the typological approach to fossil species, common at that time, this often resulted in individual species present in

two or more bioprovinces being described under several names. In extreme cases even particular ontogenetic stages of the same species have been designated as different species. In this way the bivalve taxonomy has been seriously oversplit. This terminological disorder, made worse during the 20th century, has not only limited the possibility of using bivalves for stratigraphy or palaeogeographic reconstructions, but it also has long been used to support the concept of strong endemism of the East-Paratethyan bivalve assemblages. The lack of synthetic palaeontological studies encompassing bivalves from the whole area of the Paratethyan bioprovince weakens the credibility of palaeogeographical reconstructions based on bivalves (KRACH 1979, DEMARCQ 1984, NEVESSKAJA & *al.* 1984, 1986, 1987, KÓKAY 1985, BEN MOUSSA & DEMARCQ 1992) and makes reconstruction of the history of the Paratethys basins difficult.

That is why extensive joint research work on Middle Miocene bivalve assemblages of the Central and Eastern Paratethys was undertaken in 1990 by the Museum of the Earth, Polish Academy of Sciences and the Palaeontological Institute, Russian Academy of Sciences. The purpose of this work was threefold:

- (i) to present the species composition of the bivalve assemblages from both parts of the Paratethys, first of all on the basis of palaeontological collections (preceded by re-examination of the bivalve material and updating

earlier attributions and original systematic descriptions, as well as generic and species assignment), supplemented by published data on particular localities;

- (ii) to outline the biogeographic affinities of contemporaneous, i.e. Early Badenian to Chokrakian, and Late Badenian to Konkian, bivalve assemblages from both parts of the Paratethys;
- (iii) to indicate, on the basis of revised species-level data on the bivalve assemblages, the temporal and spatial frame of connections and disconnections both within the Paratethys and between both parts of the Paratethys and the Tethys.

To avoid confusion caused by different ecological preferences of individual species, the analysis has been limited to the assemblages derived from one facies only. The sandy facies was chosen as being the best recognized, having the best representation of bivalves in museum collections, and because of the excellent preservation state of the fossils, their abundance and high taxonomic diversity.

MATERIAL

This study is based primarily on the extensive bivalve collection accumulated by the present authors over twenty years (including the joint Polish-Soviet palaeontological expedition to the West Ukraine, organized in 1988 by the Palaeontological Institute, Academy of Sciences of the USSR), supplemented by specimens from the collection of W. BAŁUK, K. KOWALEWSKI, and G. JAKUBOWSKI housed in the Museum of the Earth, Polish Academy of Sciences (abbreviation MZ) as well as from the collection of O.V. AMITROV, A.G. EBERSIN, L.B. ILJINA, R.L. MERKLIN, L.A. NEVESSKAJA, and A.A. VORONINA kept at the Palaeontological Institute, Russian Academy of Sciences (PIN). The study also included examination of the bivalve material from the collections of the following institutions:

- Institute of Geological Sciences, Polish Academy of Sciences, Cracow, Poland (ING PAN): collections of W. FRIEDBERG and W. KRACH;

- Tshernyshev Scientific and Research Museum, St. Petersburg, Russia (CNIGRM): collections of W.D. LASKAREW, N.A. SOKOLOV, and B.P. ZHIZHCENKO;
- Museum of the Natural Sciences, National Academy of Sciences of the Ukraine, Lvov, the Ukraine (former the Dzieduszyckis Museum), (MD): collection of M. ŁOMNICKI;
- Institute of Geology and Geochemistry of Combustible Minerals, National Academy of Sciences of the Ukraine, Lvov, the Ukraine (IGiGGI): collection of M.I. GRUDKA;
- Museum of the Historical Geology Department, University of St. Petersburg, Russia (LGU): collection of E. EICHWALD;
- Institute of Palaeobiology, Georgian Academy of Sciences, Tbilisi, Georgia (IP GAS): collections of K.G. BAGDASARIAN and H.M. ZHENTI;
- Palaeontological Museum of the State University of Sofia, Bulgaria (PMUS): collections of E. KOJUMDIEVA and B. STRACHIMIROV;
- Geological Institute, Bulgarian Academy of Sciences, Sofia, Bulgaria (GIN BAN): collections of I. KADIEV and P. NIKOLOV;
- Historical and Natural History Museum in Pleven, Bulgaria (IPMP): collection of I. KADIEV;
- Department of Geology and Palaeontology, Hungarian Natural History Museum, Budapest, Hungary (TTM): collections of I. CSEPREGHY-MEZNERICS, G. HALAVÁTS, and L. STRAUZ;
- Hungarian Geological Institute, Budapest, Hungary (MÁFI): collection of A. KESCKEMETI-KÖRMENDY and J. KÓKAY;
- Geological Museum, Bucharest, Romania (GMB): collection of N. ARABU, L. ARTIMHIŃULOV, A. DUŞA, and I. HUICĂ;
- Palaeontology-Stratigraphy Museum of the University in Cluj-Napoca, Romania (MUCN): collections of A. KOCH, E. NICORICI, O. NIŃULESCU, and C. PAPP;
- Museum of the Natural Sciences in Iassy, Romania (MNSJ): collection of B. IONESI;
- Department of Geology and Palaeontology, Faculty of Natural Sciences, Comenius University Bratislava, Slovakia (CUB): collection of J. ŠVAGROVSKÝ;
- National Museum, Bratislava, Slovakia (SNM): collection of J. ŠVAGROVSKÝ.

Additional information stems from the examination of the specimens from Ph. DAUTZENBERG's and M. GLIBERT's collections housed in the

Palaeontological Department of the Institut Royal des Sciences Naturelles de Belgique in Brussels (IRScNB), from M. HÖRNES' and R. SIEBER's collections deposited in the Geology-Palaeontology Department of the Naturhistorisches Museum in Vienna (NHM), from R. DOMÈNECH's and J. BATTALORI's collections kept at the Faculty of Geology, University of Barcelona (FGUB) and from collections of the Museo Geológico del Seminario in Barcelona (MGSB). Complementary information was derived from the monograph publications describing particular localities, with the exception of the Pötzleinsdorf and Steinabrunn exposures in Austria, where all the data came from publications (HÖRNES 1856-1870, KAUTSKY 1928, 1936, 1939, SIEBER 1953, 1955, 1956, 1958).

For the purpose of this study bivalve assemblages from about one hundred localities have been analyzed, thirty six of which are listed in Table 1. They are the most abundant bivalve assemblages, represented by a fairly large number of species in the collections of our home institutions (i.e. MZ and PIN), derived from the shallow-water sandy deposits in the different areas of the Paratethys. Information on some other assemblages was incorporated into columns: 11, 20 and 34.

PROVENANCES

Four hundred and twenty-eight species belonging to 178 genera and to 60 families are recognized in the investigated material, which was derived from 36 localities in the Central and Eastern Paratethys. Of the 429 species, 343 occur in the Lower Badenian, 71 in the Chokrakian, 316 in the Upper Badenian and 97 in the Konkian marine sandy facies. Data on the location of all these 36 bivalve-bearing outcrops (Text-figs 2, 3), number of recorded species and source information (about the collection, together with abbreviation of the repositories of examined bivalve material and publications) are listed below.

Lower Badenian of the Central Paratethys (Text-fig. 2)

Mikulov (former Nikolsburg) (Czech Republic, South Moravia, 50 km S of Brno); eastern margin of Moravian part of the Carpathian Foredeep; 117 species. Data from HÖRNES (1856-1870),

KAUTSKY (1936, 1939), and TEJKAL (1955), supplemented by the examined material from ŠVAGROVSKÝ's collection (CUB).

Steinabrunn (new spelling Steinebrunn) (Austria, 50 km NNE of Vienna); northern margin of the Vienna Basin; 117 species. After HÖRNES (1856-1870), KAUTSKY (1928, 1936, 1939) and SIEBER (1955, 1956, 1958).

Várpalota (Hungary, near Bakony Mts, 75 km WWS of Budapest); Hungarian part of the Danube Basin; 129 species. Data from KECSKEMETY-KÖRMENDY's and KÓKAY's collections (MÁFI) and JAKUBOWSKI's and STUDENCKA's collections (MZ), supplemented by data from STRAUZ & SZALAI (1943), KECSKEMETY-KÖRMENDY (1962), and KÓKAY (1966, 1971).

Lăpugiu and Coștei (western Romania, Banat Region, 50 km W of Deva, northern slopes of the Poiana Rusča Mts); the Bega Basin, Romanian part of the Banat Basin of the Intra-Carpathian Neogene Basins; 145 species from Lăpugiu and 151 species from Coștei. Data from collection of TTM, MUCN, ARABU's, ARTIM's, DUSA's and STANKU's collections (MGB), IONESI's collection (NHMJ), STUDENCKA's collection (MZ), and supplementary data from CHIRA (1994) and NICORICI (1977).

Małoszów (Central Poland, the Miechów Upland, 40 km NNE of Cracow); the Działoszyce Basin, western coastal zone of Polish part of the Carpathian Foredeep; 70 species. Data from the ING PAN collection described by KRACH (1947), and supplementary data after FRIEDBERG (1934-1936).

Târnene and Yasen (northern Bulgaria, 20 km W of Pleven, left bank of the river Vit); southwest of the Dacian Basin (Lom Gulf); 122 species in Târnene and 48 species in Yasen. Data from KOJUMDIEVA's collection (PMUS), KADIEV's collection (IPMP), NIKOLOV's and KADIEV's collections (GIN BAN), JAKUBOWSKI's and STUDENCKA's collections (MZ), and after KOJUMDIEVA (1960), NIKOLOV (1995), and POPOV & *al.* (1996).

Chokrakian of the Eastern Paratethys (Text-fig. 2)

Varna (northeastern Bulgaria); Varna-Balcik Depression of the Burgas Gulf; 36 species.

Based on the PMUS material collected from Varna and Samotino described by STRACHIMIROV (1960).

Belaya river (southern Russia, western Precaucasus, Republic of Adygea, 30 km S of Majkop); southern margin of the Indol-Kubanian Depression; 39 species. Based on the material from GONTSHAROVA'S, ILJINA'S and POPOV'S collections (PIN), and BAGDASARIAN'S and ZHGENTI'S collections (IP GAS).

Yaman-Dzhalga ravine (southern Russia, central Precaucasus, Republic of Karachayevo-Cherkesia, 65 km S of Stavropol); northern margin of the East Kubanian Depression; 38 species. Based on the material from GONTSHAROVA'S and MERKLIN'S collections (PIN).

Bryk Mt. (southern Russia, central Precaucasus, Stavropol Region, 55 km E of Stavropol); western margin of the Terek-Caspian Depression; 20 species. Based on the material from GONTSHAROVA'S collection (PIN) and ZHGENTI'S collection (IP GAS).

Dzhgali (western Georgia, Mingrelia Region, 100 km SE of Sukhumi, a village on the river Chanis-chali); north of the Rioni Depression in the Trans-Caucasian Strait area; 30 species. Data from the IP GAS collection described by BAGDASARIAN (1965, 1970), and from GONTSHAROVA'S and MERKLIN'S collections (PIN).

Tobedzhyk ravine (West Kazakhstan, western part of the Mangyshlak Peninsula, 100 km NW of Aktau, formerly Shevtshenko); northern margin of the South Mangyshlak Depression; 12 species. Based on the material from GONTSHAROVA'S collection (PIN), supplementary data after LIWROWSKAJA (1960).

Belek well (northwestern Turkmenistan, Krasnovodsk Peninsula, 50 km E of Krasnovodsk); Western Turkmenian Depression; 11 species. Based on the material from MERKLIN'S and POPOV'S collections (PIN).

Upper Badenian of the Central Paratethys (Text-fig. 3)

Pötzeinsdorf (Austria, Vienna 18th district); western margin of the Vienna Basin; 113 species.

After HÖRNES (1856-1870), KAUTSKY (1928, 1936, 1939), and SIEBER (1953, 1955, 1956).

Borský Mikuláš (South-West Slovakia, 60 km NNE of Bratislava, western slopes of the Malé Karpaty Mts); eastern margin of the Vienna Basin; 46 species. Data from the SNM collection described by ŠVAGROVSKÝ (1981).

Buituri (western Romania, Hunedoara Region, 20 km S of Deva); the Lower Strei-Hațeg Basin, southern part of the Transylvanian Depression; 135 species. Based on ARABU'S collection (MGB), IONESI'S collection (NHMJ), JAKUBOWSKI'S and STUDENCKA'S collections (MZ), supplementary data after MOISESCU (1954) and NICORICI (1977).

Rybnica 1, Rybnica 2 and Nawodzice (Central Poland, 40 km S of Kielce, southern slopes of the Holy Cross Mts); northern coastal zone of Polish part of the Fore-Carpathian Depression; 63 species from Rybnica 1, 78 species from Rybnica 2 and 56 species from Nawodzice. Data from the MZ collection described by STUDENCKA (1986, 1987).

Niskowa (southern Poland, 75 km SSE of Cracow); the Nowy Sącz Basin, Polish part of the Western Carpathians; 60 species. Data from the MZ collection, described by BAŁUK (1970), supplemented by data from FRIEDBERG (1934-1936).

Hołubica (the Ukraine, Ternopol Region, 90 km E of Lvov, the upper river Seret); Podolian Massif, northern part of the Halicz-Volhynian Depression; 67 species. Based on ŁOMNICKI'S collection (MD) and FRIEDBERG'S collection (ING PAN), supplemented by data after FRIEDBERG (1934-1936, 1938).

Zhabiak ravine (the Ukraine, Ternopol Region, 45 km N of Ternopol, near the village Zalesce); Podolian Massif, northern part of the Halicz-Volhynian Depression; 71 species. Data from FRIEDBERG'S collection (ING PAN), KOWALEWSKI'S and STUDENCKA & STUDENCKI'S collections (MZ), POPOV'S and VORONINA'S collections (PIN), and after FRIEDBERG (1934-1936, 1938).

Vanzhulovo (the Ukraine, Ternopol Region, 35 km NE of Ternopol, river Buhlovka); Podolian Massif, Buhlovka Basin; 64 species. Based on STUDENCKA & STUDENCKI'S collection (MZ) and GRUDKA'S collection (IGIGGI).

Varovtsy (the Ukraine, Khmielnitsky Region, 30 km W of Khmielnitsky, right bank of the river Smotritsh); Podolian Massif, northeastern part of the Halicz-Volhynian Depression; 102 species. Based on the material from AMITROV's, POPOV's and VORONINA's collections (PIN) and STUDENCKA & STUDENCKI's collection (MZ).

Bursuk (northern Moldova, Bessarabian Upland, 120 km NNW of Kishinev, on the river Dniestr); Moldavian Platform, southeastern part of the Halicz-Volhynian Depression; 51 species. Based on the material from MERKLIN's collection (PIN), supplemented by data after VOLOSHINA (1973) and YANAKEVICH (1993).

Dobrusha (northwestern Bulgaria, 80 km NNE of Sofia); southwest of the Dacian Basin (south margin of the Lom Gulf); 44 species. Examined material from the PMUS collection described by KOJUMDIEVA (1960), NIKOLOV's collection (GIN BAN) and KADIEV's collection (MNSP), both described by POPOV & *al.* (1996), and from JAKUBOWSKI's and STUDENCKA's collections (MZ).

Konkian of the Eastern Paratethys (Text-fig. 3)

Varna (northeastern Bulgaria); the Varna-Balcik Depression of the Burgas Gulf; 11 species. Data from the PMUS collection described by STRACHIMIROV (1960).

Belaya river (southern Russia, western Caucasus, Republic of Adygea, 25 km S of Majkop); southern margin of the Indol-Kubanian Depression; 44 species. Based on the material from ILJINA's, MERKLIN's and POPOV's collections (PIN), and BAGDASARIAN's collection (IP GAS).

Naspere (western Georgia, Imeretia Region, 35 km N of Kutaisi); northern margin of the Rioni Depression, the Trans-Caucasian Strait area; 12 species. Based on the material from POPOV's collection (PIN).

Agara (central Georgia, Kartli Region, 90 km WNW of Tbilisi); southern margin of the Middle Kura Depression, the Trans-Caucasian Strait area; 30 species. Data from POPOV's collection (PIN).

Aksengir Mt. (West Kazakhstan, northwestern part of the Mangyshlak Peninsula, 55 km NE of Aktau, former Shevtshenko); north margin of the South Mangyshlak Depression; 19 species. Based on the material from AMITROV's, ILJINA's, MERKLIN's, NEVESSKAJA's, and POPOV's collections (PIN).

Mynsualmaz (West Kazakhstan, northwestern cliff of the Usturt Plateau, 280 km ESE of Atrau, former Guriev); northern margin of the North Usturt Depression; 28 species. Data from MERKLIN's, POPOV's and VORONINA's collections (PIN).

Molkuduk (West Kazakhstan, northern cliff of the Usturt Plateau, draw well 340 km ESE of Atrau, formerly Guriev); northern margin of the North Usturt Depression; 35 species. Based on the material from AMITROV's, MERKLIN's, POPOV's, and VORONINA's collections (PIN).

Sarykamysh (northern Turkmenistan, southeastern margin of the Usturt Plateau, 200 km WSW of Nukus); Sarykamysh Depression; 31 species. Based on the PIN material from Karashoky, Karashor and Sarykamysh (MERKLIN & NEVESSKAJA 1955).

CHECKLIST OF PARATETHYAN BIVALVES

In Table 1 all of the Paratethyan bivalve species from the Middle Miocene sandy facies deposits are listed. The present authors have updated the original material from all available collections housed in numerous European institutions, and the list given here is credible.

Of the total number of 429 bivalve species recorded in Middle Miocene shallow-water sandy deposits of the Paratethys, three new species have been established, viz. *Lucina kadievi* POPOV, 1996, *Acanthocardia (Acanthocardia) allae* STUDENCKA & POPOV, 1996 and *Acanthocardia (A.) antonihoffmani* STUDENCKA & POPOV, 1996.

In the case of four others taxa attribution at species level was not possible. They are: *Crassatella (Landina) sp.*, *Pholas sp.*, *Martesia sp.* and *Clavagella sp.*

The following species have not previously been reported from the Middle Miocene of the Central Paratethys: *Nucula (Lamellinucula) cromata* (SORGENFREI), recognized hitherto from the Middle Miocene of Denmark; *Barbatia (Cucullaearca) vincenti* (COUFFON) and *Barbatia (Obliquarca) dentiens* (COSSMANN & PEYROT), both recorded in the Lower Miocene of France; *Glycymeris (Glycymeris) nummaria* (LAMARCK), ranging from the Early Miocene to Pliocene of the Mediterranean Province and from Early Miocene to Recent of the Eastern Atlantic; *Ctenoides tenera* (CHEMNITZ), reported from the Lower Miocene and Pliocene of Italy; *Pterolucina schencki* (CHAVAN) recorded from the Lower Miocene of France; *Barbierella miobarbieri* (SACCO), described from the Lower Miocene of Italy; *Glans (Centrocardita) squamulosa* (NYST), reported from the Middle Miocene of Belgium; *Crassatella (Landina) sp.*; *Miocardiopsis carinata* (DESHAYES), collected from Eocene of France; *Miocardiopsis deshayesi* (BELLARDI), described in the Lower Miocene of Italy; *Tivelina noaillanensis* (COSSMANN & PEYROT), recognized in the Lower Miocene of France; and *Gastrochaena (Spengleria) miotaurinensis* (SACCO) described from the Middle Miocene of Italy.

To compile species-level data on the bivalve faunas it was necessary, in many cases, to revise the former taxonomic schemes quite substantially. Data on the generic and specific position of many taxa, and species synonymies have been given in the chapter *Taxonomic remarks*. With a few exceptions, the classification follows NEWELL *in* MOORE (1969, 1971).

Columns 3-10, 12-18, and 20-42 show the occurrences of particular species in all of the 36 examined outcrops, and their abundance in the collections housed in the Museum of the Earth, Polish Academy of Sciences (Warsaw), the Palaeontological Institute, Russian Academy of Sciences (Moscow), and in the Museum of the Natural Sciences, National Academy of Sciences of the Ukraine (Lvov). For species housed in the indicated institutions the following symbols of frequency are used: **R** (rare) – up to 5 specimens, **C** (common) – up to 50 specimens, and **A** (abundant) – over 50 specimens. The letter **X** indicates that occurrences of species are based on monograph publications and/or other museum collections.

In column 11, the letter **T** indicates finds of species in both Tarkhanian and Chokrakian strata, while **X** indicates species records only in other Chokrakian outcrops.

In column 20, species reported from both Lower and Upper Badenian strata are indicated by the letter **E**, whereas the letter **X** indicates occurrences of species restricted to other Upper Badenian outcrops.

In columns 43 and 44, the letter **L** indicates occurrences of species in Lower Miocene deposits of the Atlantic (France, Portugal) and Mediterranean (Marocco, Italy and Spain) bioprovinces, respectively, whereas the letter **M** indicates occurrences of species in Middle Miocene strata of these two bioprovinces.

Data after BEN MOUSSA (1994), BERKELEY-COTTER (1956), COSSMANN & PEYROT (1909-1914), DOLLFUS & DAUTZENBERG (1902-1920), GLIBERT & VAN DE POEL (1965-1970), LAURIAT-RAGÉ (1981), MALATESTA (1974), ROBBA (1971), SACCO (1897-1901), DA VEIGA FERREIRA (1951, 1956, 1961), VENZO & PELOSIO (1963), ZBYSZEWSKI (1957), and supplementary data from the IRScNB, FGUB and MGSB collections.

TAXONOMIC REMARKS

The systematic arrangement of bivalve species in the present paper follows the order of families, genera and subgenera given in the *Treatise on Invertebrate Paleontology* (MOORE 1969, 1971). The arrangement of families has not generally been modified, except the families Pectinidae and Cardiidae, the systematics of which follows WALLER (1991, 1993) and POPOV (1977), respectively. Most modifications of generic and subgeneric categories result from studies undertaken after publication of the *Treatise*. Because younger synonyms of many species recorded in the Middle Miocene deposits of the Paratethys have been recognized, it is necessary, in the present authors' opinion, to present lists of these synonyms. To facilitate finding a specific taxon, the species below are listed in the same order as presented in Table 1.

No	Upper Badenian of the Central Paratethys													Konkian of the Eastern Paratethys										Late or M. Miocene, Atlantic	Late or M. Miocene, Mediterranean	
	Other localities	Pötziensdorf	Borský Mikuláš	Buituri	Rybnica 1	Rybnica 2	Nawodzice	Niskowa	Holubica	Zhabiak ravine	Vanzhulovo	Varovtsy	Bursuk	Dobrusha	Other localities	Varna	Belaya river	Naspere	Agara	Aksengyr Mt.	Mynsualmaz	Molkuuk	Karashoky			
19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	
Nuculidae																										
1	E	X	X	C	A	A	C	C	A	C	C	C		X											LM	M
2	E	X																							LM	
3	E			X	A	A	A	C	A	C		A														
4	E																									M
5				C																					M	
6	E													R											M	M
Malletiidae																										
7																										
Nuculanidae																										
8																										M
9	E																									
10	E	X											X												LM	M
11	E		X	A	C	A	R		C	R	R	R			X						R				M	M
12																										M
13																										
14																									M	LM
15																									M	M
Solemyidae																										
16	E	X																								M
Arcidae																										
17	E	X		R				R			R				X		C			R					LM	M
18	E																									M
19	E	X		R	R			R																	LM	M
20	E	X		C		C	C	R	C		R	R	R		X		C								LM	M
21	E									R																M
22	E																									
23																									LM	
24	E				R																					
25																									M	
26	E				R	R																			LM	M
27	E	X							C		A															
28																										
29	E	X		C		R	R	C		R		R	A	C	X										M	M
30																									LM	M
31	E	X		X				R						C	X				C		R	C	C		M	M

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Limidae																	
123	<i>Lima (Lima) lima</i> (Linnaeus)			X	R	X		X	X								
124	<i>Ctenoides tenera</i> (Chemnitz)								R								
125	<i>Limaria (Limaria) tuberculata</i> (Olivi)							X		T		R					
126	<i>Limaria (L.) hians</i> (Gmelin)			X													
127	<i>Limaria (Limatulella) loscombii</i> (G.B. Sowerby)									X							
128	<i>Limatula subauriculata</i> (Montagu)		X		X	X	X										
129	<i>Limatula sulcata</i> (Brown)				R												
130	<i>Limea (Limea) strigilata</i> (Brocchi)		X		R	X											
131	<i>Limea (Gemellina) sacki</i> Philippi																
Gryphaeidae																	
132	<i>Hyotissa hyotis</i> (Linnaeus)	X			X												
133	<i>Neopycnodonte navicularis</i> (Brocchi)	X	X		X	X	X	X		T							
Ostreidae																	
134	<i>Crassostrea gryphoides</i> (Schlotheim)	X	X	R		X											
135	<i>Crassostrea miocucullata</i> (Schaffer)			X													
136	<i>Ostrea (Ostrea) lamellosa offreti</i> (Kilian)	X	X				X										
137	<i>Ostrea (O.) fimbriata</i> Grateloup			X	X	X	X										
138	<i>Cubitostrea digitalina</i> (Eichwald)	X	X	X	X	X	X	X		X							
Lucinidae																	
139	<i>Lucina (Lucina) orbicularis</i> Deshayes						R										
140	<i>Lucina (L.) callipteryx</i> Tournouër						R										
141	<i>Lucina (Lucina) kadievi</i> Popov								R								
142	<i>Barbierella miobarbieri</i> (Sacco)								R								
143	<i>Callucina (Pseudolucinisca) michelottii</i> (Mayer)				X	X		X									
144	<i>Codakia (Codakia) leonina</i> (Basterot)	X	X	X	R	X		R									
145	<i>Codakia (Epilucina) haidingeri</i> (Hörnes)	X	X					X									
146	<i>Ctena (Ctena) decussata</i> (da Costa)	X	X	R	R	X		R	X								
147	<i>Ctena (C.) exigua</i> (Eichwald)	X	X		X	R	X										
148	<i>Linga (Linga) columbella</i> (Lamarck)	X	X	R	X	X		X									
149	<i>Linga (Bellucina) agassizi</i> (Michelotti)	R	X	X	R	X		X									
150	<i>Loripes (Loripes) dujardini</i> (Deshayes)	X	X	X			X	X		T	X	R	R				
151	<i>Loripes (Microloripes) dentatus</i> (Defrance)	X	X	X	X	X	X	X		T	X	C	C				
152	<i>Loripes (M.) neglectus</i> (Basterot)	C			R	R											
153	<i>Megaxinus (M.) bellardianus</i> (Mayer)	X			X	X											
154	<i>Megaxinus (M.) ellipticus</i> (Borson)																
155	<i>Megaxinus (M.) incrassatus</i> (du Bois)		X	X	X	C	X	X	X								
156	<i>Megaxinus (M.) transversus</i> (Bronn)	X	X				X										
157	<i>Parvilucina submichelottii</i> Sacco				R	R											
158	<i>Myrtea (Myrtea) spinifera</i> (Montagu)		X	X	R	R		C									
159	<i>Myrtea (M.) strigillata</i> Reuss					R											
160	<i>Gonimyrtea meneghini</i> (Stefani & Pantanelli)				X	X											
161	<i>Lucinoma borealis</i> (Linnaeus)		X			X											
162	<i>Montilora (Montilora) elegans</i> (Defrance)																
163	<i>Anodontia (Loripinus) fragilis</i> (Philippi)		X		X			X									
164	<i>Pterolucina schencki</i> Chavan				X			X									
165	<i>Saxolucina (Plastomiltha) suessi</i> (Kautsky)	R	X														
166	<i>Divalinga ornata</i> (Agassiz)			X	X	R		X									
167	<i>Lucinella divaricata</i> (Linnaeus)					X											
Thyasiridae																	
168	<i>Thyasira (T.) flexuosa flexuosa</i> (Montagu)	R	X		X		X										
169	<i>Thyasira (T.) flexuosa laevis</i> Zhizhchenko									T					R		

19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44		
211	X						R																				
212	E	X																									
Neoleptonidae																											
213											R		X														
Carditidae																											
214	E	X																							M	M	
215	E			R																					LM		
216	E	X											R			R									LM		
217																									L		
218	E																										
219	E		X																								
220	E			X																							
221	E	X		X		C	A	R																	M		
222	E	X		X							R		C		X	R					A	A	C		M		
223																									M		
224	E			X					A	C	R	R	X	X													
225																											
226																											
227	E	X	X	R						X															M	M	
228	E									R	R	R	X													M	
229				C																					L		
230	E									R	C	C	C		X							R					
231	E	X	X	C					A	R	R	C	C	X											M	M	
232																									L		
Astartidae																											
233					R	R																					
234	E				R	R																					
235	E			X																							
Crassatellidae																											
236													R														
237	E					R																			LM	M	
238	E																										
Cardiidae																											
239	E	X	X	X										X											LM	M	
240	E			X									X	X	X			R	C				C	LM	M		
241																											
242	E				C	A	R																		M		
243	X										R	C															
244															X					R	C	A					
245	E			R						R		C		R													
246	X						R	C		R		R															
247																											
248	E				R	C	R								X		C								LM	M	
249	X																										
250															X									C			
251	E	X	X	R	R	A	R	C	R		R	R	A	X											M	M	
252																											
253																											
254	E				R	C	C	R	C						X				R	C	R	R					
255	E				C	C	C	C		R					X												
256	E			C						R	R	C			X	X	C	R		C		A					

19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44		
257																											
258	E			C		R		C	R	R	C				X												
259																											
260																									L		
261	E	X		C	R	C			R	C	R	R													M		
262	E	X		X		R			C	R	R	C	A	X	X		C		R		R	C	R	LM	M		
263	E			A						A		A			X		A	R									
264	E			R	A	C	C																	L			
265	E	X		R				A	R	C	R	C			X		C	R		C		R					
266	E	X		R						R		R															
267																								L			
268	E			X																				LM	M		
269	E	X	X	X						C	R	R															
Mactridae																											
270																									M		
271	E			R					R			R	R		X	R	A		R			R	R	LM	M		
272																											
273	E					R									X												
274	E											R													M	M	
275	E			X					C			C	R		X						C	A	C	L	L		
276	E				R		R		R	R		R													L		
277																									L	M	
278	E	X																						LM	M		
279	E				R	R			R				R	X	X		R						R	LM			
Cardiliidae																											
280	E																										
Mesodesmatidae																											
281	E	X		R			R																				
282																											
283																											
284	X				A	R					C	R			X	X											
285	E	X		R	A	A	C	R	R	C	C	A	C												LM	M	
286	X												C		X	X	A						A	C			
Solenidae																											
287	E	X																									
288	E								X			A			X								R	LM			
Cultellidae																											
289	E					C																					
290	E																										
291																											
292					C	C	R		R			R															
293	E					R	C		C			C													M		
Tellinidae																											
294	E			X				C	R		R	C			X							R					
295	E									R					X										LM	M	
296	E			X								C												LM			
297	E			R																				LM	LM		
298	E														X												
299																											
300	E	X	X	R				R	A	C	R	C	R	X	X		R		R			C		LM	M		
301	E	X	X	R			C	R	C			R	C											LM	M		

Family **Nuculidae**

- 3 *Nucula (Nucula) nitidosa*
WINCKWORTH, 1930
pro *Nucula nitida* SOWERBY, 1833, non *Nucula nitida* (BROCCHI, 1814)
= *Nucula nitida* var. *turgida* MARSHALL in
LECKENBY & MARSHALL, 1875

This species was for a long time known as *Nucula nitida* SOWERBY, 1839, and described in detail by FORBES & HANLEY (1849). However, WINCKWORTH (1930, p. 14) found that this name had been used by BROCCHI in 1814 to describe *Arca nitida*, which was assigned by DEFRANCE in 1825 to the genus *Nucula*. Therefore, WINCKWORTH proposed a new name, *Nucula nitidosa* to replace *Nucula nitida*.

Recently it was found that these two species are not congeneric, SOWERBY's species retaining its assignment to the genus *Nucula*, while BROCCHI's species belongs to the genus *Yoldia*. However, according to Art. 59b of the I.C.Z.N. (1985), a junior secondary homonym replaced before 1961 is permanently invalid. On the other hand, *Nucula turgida* MARSHALL is a younger homonym of *Nucula turgida* GOULD, 1846, as demonstrated by BOWDEN & HEPPEL (1968).

Family **Nuculanidae**

- 10 *Nuculana (Lembulus) emarginata*
(LAMARCK, 1819)
= *Leda pella* var. *magna* BAJARUNAS, 1910
= *Leda (Lembulus) pella caucasica*
ZHIZHCENKO, 1934
= *Leda (Lembulus) pella elongata* ZHIZHCENKO,
1934
= *Leda pella submarginata*
ZHIZHCENKO, 1937
= *Leda (Lembulus) pella tarchanica* MERKLIN,
1950
- 13 *Nuculana (Saccella) prendeli*
(ANDRUSSOW, 1904)
= *Leda (Jupiteria) subfragilis bosporica*
MERKLIN, 1950
= *Leda (Jupiteria) subfragilis subbosporica*
MERKLIN, 1950
= *Leda (Jupiteria) tenuivalva*
MERKLIN, 1950

Family **Arcidae**

- 18 *Acar clathrata* (DEFRANCE, 1816)
= *Arca bohemica* REUSS, 1860

The taxon *Acar* GRAY, 1857 is here considered as being not a subgenus of *Barbatia* GRAY, 1842 but a separate genus. The characteristic feature of *Acar*, apart from the trapezoidal outline of the shell with a sharp keel, is its microstructure. The outer shell layer of *Barbatia* has crossed lamellar structure composed of radial lamellae, while in *Acar* these lamellae build only ribs whereas the crossed lamellar part lying below them consists of concentric lamellae (POPOV 1992, pp. 5-6). The present authors agree with the statement of CADÉE & JANSSEN (1993) that REUSS' species *Arca bohemica* described from the Miocene (Badenian) of Bohemia (REUSS 1860, pp. 241-242, Pl. 3, Fig. 13) is synonymous with *Acar clathrata* (DEFRANCE, 1816).

- 20 *Barbatia (Barbatia) barbata*
(LINNAEUS, 1758)
= *Arca eichwaldi* FRIEDBERG, 1929
- 23 *Barbatia (Cucullaearca) vincenti*
(COUFFON, 1905)
?= *Acar tauroclathrata* SACCO, 1898
= *Barbatia (Cucullaearca) bohemica* of NIKOLOV
(1995), non REUSS, 1860

CADÉE & JANSSEN (1993) considered REUSS' species *bohemica* to be a younger synonym of *Acar clathrata* (DEFRANCE, 1816); therefore the correct name for the specimens from Middle Miocene deposits of France attributed previously to *Arca (Acar) bohemica* by COSSMANN & PEYROT (1913, pp. 185-187, Pl. 9, Figs 15-18, 33-37) and DOLLFUS & DAUTZENBERG (1913, pp. 343-344, Pl. 29, Figs 17-32) is the COUFFON's name *vincenti*. This latter species was also recorded in Lower Badenian strata in Bulgaria (NIKOLOV 1995, p. 131, Pl. 1, Figs 3-4, POPOV & al. 1996, p. 159).

24 The taxon *Obliquarca* SACCO, 1898 is here considered as being not a synonym of *Barbatia* GRAY, 1842, but as its subgenus. *Obliquarca*, unlike *Barbatia* s.s., has a modioliform shell with a shifted umbo and a distinct ridge. The stratigraphical evidence indicates that morphological differences between these subgenera have been conspicuous from at least Eocene time.

27 *Anadara (Anadara) anomala*
(EICHWALD, 1830)
= *Arca hungarica* HÖRNES, 1864

28 *Anadara (Anadara) bosporana*
(DAVIDASCHVILI, 1932)
= *Arca turonica* var. *giaurtapensis* GRIGOROVICH-BERESOWSKY, 1925
= *Arca turonica* var. *aksaica* ZHIZHCENKO, 1934
= *Arca (Anadara) inopiosa* ZHIZHCENKO, 1936
= *Arca turonica zageniensis* ANANIASCHVILI, 1964
= *Arca turonica minuta* BAGDASARJAN, 1970

29 *Anadara (Anadara) diluvii* (LAMARCK, 1805)
= *Arca diluvii* var. *palotensis* STRAUZ & SZALAI, 1943
= *Arca (Anadara) suessi* KAUTSKY, 1925

Family Noetiidae

37 MALATESTA (1974, pp. 25-26, Pl. 1, Fig. 6a-6b) proposed a new genus *Hoernesarca*, with *Arca rollei* HÖRNES, 1864 as the type species, ranging from the Middle Miocene (Mediterranean and Paratethys bioprovinces) to the Pliocene.

Family Mytilidae

45 *Mytilus hoernesianus* KAFANOV, 1987
pro *Mytilus fuscus* HÖRNES, 1867, non *Mytilus fuscus* GMELIN, 1791
= *Mytilus fuscus* var. *pulcher* ZHIZHCENKO, 1936
= *Mytilus razmyslova* MERKLIN & NEVESSKAJA, 1955

The synonymization of BAGDASARJAN's species *Mytilus tkvarcheliensis* and HÖRNES' *fuscus* suggested by GONTSHAROVA (1989, p. 74) is not accepted here. Examination of the new material from the western Precaucasus has revealed that BAGDASARJAN's *tkvarcheliensis* actually belongs to the genus *Perna* RETZIUS, 1788.

46 *Brachidontes biali*
(COSSMANN & PEYROT, 1912)

In the present authors' opinion all specimens from both the Polish and Ukrainian parts of the Fore-Carpathian Depression previously assigned by FRIEDBERG (1936, pp. 188-189, Pl. 29, Fig. 18), JAKUBOWSKI (1972, pp. 73-79, Text-pl. 4,

Figs 1-23, Pl. 4, Figs 1-23), and KRACH (1981, p. 36, pl. 6, Figs 3-6) to *Septifer oblitus* (MICHELOTTI, 1847) should be included in *Brachidontes biali*. The principal difference between them is the absence of the internal septum beneath the beaks of *B. biali*, while the shell shape and the sculpture are indistinguishable.

48 *Brachidontes marginatus* (EICHWALD, 1830)
= *Modiola submarginata* LASKAREW, 1903
?= *Modiola (Brachidontes) convexa* OSAULENKO, 1936

50 *Mytilaster volhynicus* (EICHWALD, 1829)
= *Modiolus incrassatus* D'ORBIGNY, 1844
= *Modiolus subincrassatus* D'ORBIGNY, 1847
= *Modiolus volhynicus* var. *buglovensis* GATUEV, 1916
= *Modiolus volhynicus* var. *sultanensis* GATUEV, 1916
= *Modiola kolesnikovi* LIWEROWSKAJA, 1935
= *Modiolus lucidus* ZHIZHCENKO, 1936

The synonymization of HÖRNES' species *Modiola latochae* and *M. volhynicus*, suggested by STUDENCKA (1986, p. 32) is recognized here as invalid. Examination of the Sarmatian and Recent specimens of *Modiolus minimus* (POLI, 1795) has revealed that HÖRNES' *latochae* is conspecific with POLI's *minimus*.

60 *Musculus (Musculus) conditus*
(MAYER, 1853)
= *Musculus conditus* var. *concinna* MERKLIN, 1950
= *Musculus conditus sartasi* MERKLIN & NEVESSKAJA, 1955

63 *Modiolus adriaticus* (LAMARCK, 1819)
?= *Modiola solitaria* NIEDZWIEDZKI, 1886
= *Modiolus brocchi* var. *ustjurtensis* ZHIZHCENKO, 1937
= *Modiola (Modiola) exbrocchi* of KOJUMDIEVA (1960), non SACCO, 1898

The type specimen of *Modiola solitaria* is lost, but the examination of the figure and description given by NIEDZWIEDZKI (1886, pp. 16-17, Pl. 1, Fig. 2) reveals close resemblance of *solitaria* and LAMARCK's *adriaticus*, which suggests that *solitaria* could be included in the latter species. In the present authors' opinion the specimens from Niskowa (Poland) identified by

BALUK (1970, pp. 133-134, Pl. 3, Fig. 8) as *Modiolus hoernesii solitarius* (NIEDZWIEDZKI, 1886) belong to LAMARCK's species *adriaticus*.

Family **Isognomonidae**

- 71** *Isognomon (Isognomon) radiatus*
(HÖRNES, 1867)
= *Perna ciscaucasica* DAVIDASCHVILI, 1932

Family **Pectinidae**

The systematic arrangement of scallops applied here follows WALLER (1991, 1993).

- 73** *Delectopecten similis* (LASKEY, 1811)
= *Pecten exilis* EICHWALD, 1853

- 75** *Palliolium bittneri* (TOULA, 1899)
= *Pecten elini* ZHIZHCHENKO, 1952

- 77** *Flexopecten lilli* (PUSCH, 1837)
= *Pecten lilliformis* HILBER, 1882
= *Pecten neumayri* HILBER, 1882
= *Pecten sturi* HILBER, 1882
= *Pecten wimmeri* HILBER, 1882
= *Pecten depereti* FRIEDBERG, 1907

- 79** *Flexopecten scissus* (FAVRE, 1869)
= *Pecten resurrectus* HILBER, 1882
= *Pecten richthofeni* HILBER, 1882
= *Pecten scissoides* HILBER, 1882
= *Pecten subscissoides* HILBER, 1882
= *Pecten wolfi* HILBER, 1882
= *Pecten wulkae* HILBER, 1882
= *Pecten wulkaeformis* HILBER, 1882
= *Chlamys (Flexopecten) rybnicensis*
FRIEDBERG, 1936

Several species distinguished by HILBER (1882, pp. 20-22, 28-30) on the base of minute differences in sculpture are here recognized to be conspecific with FAVRE's species *scissus*. Another of HILBER's species, *posthumus*, was tentatively synonymized with *scissus* by STUDENCKA (1986, pp. 40-43). Examination of Polish and Ukrainian specimens has revealed that HILBER's *posthumus* and FAVRE's *scissus* represent different species. GLIBERT (1945, pp. 73-74, Pl. 5, Fig. 1) considered *P. lamali* NYST, 1843 and *P. scissus* FAVRE, 1869 to be junior synonyms of *P. lilli* PUSCH, 1837. In

the present paper FAVRE's *scissus* and PUSCH's *lilli* are recognized as different species. The presence or absence of small square nodes at the intersection of the radial ribs and commarginal lamellae (fairly distinct on small specimens, but present only in the umbonal region of larger ones) is pointed out here as a distinctive feature separating these two species. However, the similarity of NYST's *lamali* (after its description and illustration given by GLIBERT 1945) and FAVRE's *scissus* is so striking that these two forms may be treated as conspecific. Having no access to the original Belgian material, the present authors prefer to preserve the well-known name *scissus*.

- 83** *Amussiopecten spinulosus attenuatus*
KOJUMDGIEVA, 1960

As demonstrated by KOJUMDGIEVA (1960), pectinids recorded in both the Polish and Ukrainian parts of the Fore-Carpathian Depression, recognized as *Pecten koheni* FUCHS, 1876 (HILBER 1882, pp. 32-33, Pl. 4, Figs 10-12, FRIEDBERG 1936, 223-235, Pl. 39, Figs 8-10) represent, in fact, a new variety of MÜNSTER's species *spinulosus*. This variety named by KOJUMDGIEVA (1960, p. 70, Pl. 23, Fig. 9, Pl. 24, Figs 2-4) *attenuatus* should be, according to NICORICI (1977, pp. 136-137), considered as a subspecies of MÜNSTER's *spinulosus*. Accordingly, all Parathyran specimens referred, following HILBER (1882) to FUCHS' species *koheni* (CSEPREGHY-MEZNERICS 1960, FRIEDBERG 1936, KAZAKOVA 1952, KRACH 1954, WOŻNY 1962, ZELINSKAJA & *al.* 1968, YANAKEVICH 1993), are here assigned to *Amussiopecten spinulosus attenuatus*.

- 89** *Gigantopecten nodosiformis*
(DE SERRES *in* PUSCH, 1837)

The taxonomic position of DE SERRES' species *nodosiformis* has changed over time, as indicated by BONGRAIN (1988) and STUDENCKA & STUDENCKI (1988). Studies by BONGRAIN have indicated its generic attribution to *Pecten* MÜLLER, 1776, and confirmed the correctness of UGOLINI's (1906) opinion concerning the replacement of the name *Macrochlamys* SACCO, 1897 by *Gigantopecten* ROVERETO, 1899 because of the homonymy of the former with *Macrochlamys* BENSON, 1832. DE SERRES' taxon is here considered as being not a temporal subspecies of the BROCCHI's *latissima* but as repre-

senting a distinct species (cf. STUDENCKA & STUDENCKI 1988, p. 27).

99 *Crassadoma multistriata* (POLI, 1795)

According to WALLER (1993, pp. 212-217, Figs 5a-b, d-e, g-h; 6c-l), the species originally named *Ostrea pusio* LINNAEUS, 1758 and *Ostrea multistriata* POLI, 1795, represent two distinct species of the genus *Crassadoma* BERNARD, 1986, distinguishable from each other on the basis of the surface microsculpture of the left beak and presence or absence of cementation and small foliated-calcite umbonal transgression on the inner surface.

102 *Aequipecten opercularis* (LINNAEUS, 1758)

- = *Pecten trigonocosta* HILBER, 1882
- = *Pecten (Aequipecten) domgeri* MIKHAILOVSKY, 1903
- = *Pecten (Aequipecten) hilberi* MIKHAILOVSKY, 1903
- = *Pecten (Aequipecten) domgeri* var. *derbentica* GRIGOROVICH-BERESOVSKY, 1925
- = *Pecten malvinae* var. *tschokrakensis* DAVIDASCHVILI, 1932

103 *Aequipecten diaphanus* (DU BOIS, 1831)

- = *Pecten galicianus* FAVRE, 1869
- = *Pecten sartaganicus* ANDRUSSOW, 1917
- = *Chlamys diaphana* var. *demmata* PAVLINOVA-ILJINA, 1957
- ?= *Chlamys biaense* CSEPREGHY-MEZNERICS, 1960
- ?= *Chlamys ramosense* CSEPREGHY-MEZNERICS, 1960

Both *biaense* and *ramosense* have been tentatively synonymized with *diaphana* merely on the basis of the descriptions and illustrations given by CSEPREGHY-MEZNERICS (1960, pp. 28-29, Pl. 19, Figs 3-6, 9-15; Pl. 34, Fig. 12) because the original Hungarian material could not be examined.

107 *Aequipecten malvinae* (DU BOIS, 1831)

- = *Pecten flavus* DU BOIS, 1831
- = *Pecten rectangulus* DU BOIS, 1831
- = *Pecten pulchellinus* DU BOIS, 1831

108 *Aequipecten praetrigonocostoma* (ZHIZHCENKO, 1936)

- = *Chlamys (Aequipecten) tarchanicus* MERKLIN, 1950

110 *Aequipecten scabrellus* (LAMARCK, 1818)

- = *Pecten niedzwiedzki* HILBER, 1882
- = *Pecten lomnickii* HILBER, 1882

111 *Aequipecten varnensis* (TOULA, 1892)

- = *Chlamys pertinax* ZHIZHCENKO, 1934

Family **Limidae**

125 *Limaria (Limaria) tuberculata*

- (OLIVI, 1792)
- = *Limaria (Mantellum) skeliensis* MERKLIN, 1950

Specimens of this species have been previously reported from the Paratethyan Miocene (HÖRNES 1867, pp. 387-389, Pl. 54, Fig. 5; FRIEDBERG 1936, pp. 203-204, Pl. 31, Fig. 7; KOJUMDIEVA 1960, pp. 74-75, Pl. 26, Fig. 1; GONTSHAROVA 1989, pp. 96-97, Pl. 11, Figs 1-3) under the name *Lima (Mantellum) inflata* (CHEMNITZ, 1784). As demonstrated by COX & HERTLEIN (*in* MOORE 1969, p. N389) this species, originally described non-binominally by CHEMNITZ, was named binominally by LAMARCK and LINK, independently, in 1807. However, LAMARCK's name *Lima inflata*, in spite of having priority, cannot be used because it is a junior secondary homonym of *Ostrea inflata* GMELIN, 1791.

Family **Gryphaeidae**

132 *Hyotissa hyotis* (LINNEAUS, 1758)

The Austrian specimens ascribed by HÖRNES (1870, pp. 439-441, Pl. 72, Figs 3-8) to *Ostrea plicatula* GMELIN and *O. crassicostata* SOWERBY should, according to SIEBER (1955, p. 176), be attributed to *Pycnodonte squarrosa* (DE SERRES, 1843). However, FRENEIX & *al.* (1987, pp. 3-5, Pl. 1, Figs 3-4) demonstrated that the difference in the outline of the adductor muscle scar between *squarrosa* and LINNEAUS' species *hyotis* reflects intraspecific variability, and considered *squarrosa* to be synonymous with *hyotis*. Consequently, the Paratethyan specimens assigned either to *crassicostata* or *plicatula* (HÖRNES 1870, SCHAFFER 1910, FRIEDBERG 1936, TEJKAL 1956) are recognized in the present paper as *Hyotissa hyotis*.

- 133** *Neopycnodonte navicularis*
(BROCCHI, 1814)
= *Ostrea leopolitana* NIEDŹWIEDZKI, 1909

This species, common in the Miocene Paratethyan strata, was also referred to *N. cochlear* (POLI, 1791). FRENEIX (1975, pp. 443-448, Text-figs 14-15) considered *navicularis* and *cochlear* as two distinct species, the latter ranging from the Pliocene to Recent.

Family **Ostreidae**

- 136** *Ostrea (Ostrea) lamellosa offreti*
(KILIAN, 1889)

As demonstrated by FRENEIX & *al.* (1988, pp. 5-6), the Miocene oysters recognized as *Ostrea edulis* var. *boblayei* DESHAYES, 1833 (DOLLFUS & DAUTZENBERG 1920, STEININGER & *al.* 1971) should be attributed to *Ostrea (O.) lamellosa offreti* (KILIAN, 1889). Accordingly, the Paratethyan oysters from both Mikulov and Małoszów are assigned to this species.

- 138** *Cubitostrea digitalina* (EICHWALD, 1830)
= *Ostrea digitalina* var. *caucasica*
ZHIZHCENKO, 1936

Family **Lucinidae**

- 143** *Callucina (Pseudolucinisca) michelotti*
(MAYER, 1858)

The generic position of the species originally named *Lucina michelotti* MAYER, 1858 seems to be poorly recognized. SACCO (1901, p. 85, Pl. 29, Figs 12-16) and KOJUMDGIEVA (1960, p. 30, Pl. 9, Figs 14-15) assigned it to *Dentilucina* P. FISCHER, 1887, while COSSMANN & PEYROT (1912, pp. 696-697, Pl. 28, Figs 47-50), and FRIEDBERG (1934, pp. 106-107, Pl. 19, Figs 14-15) placed it in *Phacoides* AGASSIZ, 1845. CHAVAN (*in* MOORE 1969, p. N492) synonymized both *Dentilucina* and *Phacoides* with *Lucina* BRUGUIÈRE, 1797. SIEBER (1955, p. 180) placed MAYER's species into *Montilora* IREDALE, 1900 (treated as a subgenus of *Cavilucina* P. FISCHER, 1887), whereas according to NEVESSKAJA & *al.* (1993, p. 114, Pl. 26, Figs 2-5) *michelotti* belongs to *Gonimyrtea* MARWICK, 1929. However, in the present

authors' opinion, the crenulation of the inner shell margin and the presence of reticulate ornamentation on the juvenile stages of the shell suggest the affinity of *michelotti* with *Pseudolucinisca* CHAVAN, 1959, the latter being a subgenus of *Callucina* DALL, 1901.

- 151** *Loripes (Microloripes) dentatus*
(DEFRANCE, 1823)
= *Lucina nivea* EICHWALD, 1830
= *Loripes dentatus* var. *hoernesii*
BOGSCH, 1936

The present authors agree with the statement of COSSMANN & PEYROT (1911, pp. 641-642) who treated *Microloripes* COSSMANN, 1910 (with *Lucina dentata* DEFRANCE as the type species) as a subgenus of *Loripes* POLI, 1791, and considered it to be ancestral to the Early Miocene *Loripes* s.s., whereas CHAVAN (*in* MOORE 1969, pp. N499) placed *Microloripes* as a subgenus of *Parvilucina* DALL, 1910.

- 164** *Pterolucina schencki* CHAVAN, 1942
= *Miltha koleznikovi*
MERKLIN & NEVESSKAJA, 1955
= *Megaxinus bellardianus sandecianus*
BAŁUK, 1970

Family **Ungulidae**

- 173** *Felaniella brevifulcrata*
(COSSMANN & PEYROT, 1912)
= *Diplodonta holubicense* FRIEDBERG, 1929

- 174** *Felaniella trigonula* (BRONN, 1831)
= *Diplodonta subtrigonula*
ZHIZHCENKO, 1936

Family **Chamidae**

- 176** *Chama (Psilopus) gryphoides*
LINNAEUS, 1758
= *Chama austriaca* HÖRNES, 1861
= *Chama minima* TOULA, 1890
= *Chama benoisti* COSSMANN & PEYROT, 1912
= *Chama toulai* DAVIDASCHVILI, 1932
= *Chama gryphoides* var. *konkensis*
PAVLINOVA-ILJINA, 1957
= *Chama gryphoides borsodensis*
CSEPREGHY-MEZNERICS, 1969

Family **Carditidae**

221 The taxon *Scalaricardita* SACCO, 1899 is here considered to be not a subgenus of *Cyclocardia* CONRAD, 1867 but a separate genus. The characteristic feature of *Scalaricardita*, apart from the small-sized triangular shell, is the presence of anterior and posterior lateral teeth in the hinge. POPOV (1983, pp. 26, 28-36) stated that *Scalaricardita* is a principally Miocene to Pliocene European genus, while *Cyclocardia* is a Pacific and North-West Atlantic genus ranging from the Eocene to Recent.

- 228** *Megacardita laticosta* (EICHWALD, 1830)
 = *Cardita scabricosta* of HÖRNES (1867), non MICHELOTTI, 1847
 = *Cardita crassa* var. *vindobonensis* SACCO, 1899
 = *Beguina* (*Mytilicardita*) *crassa longata* SIEBER, 1956

SACCO (1899, p. 8) proposed the varietal name *vindobonensis* for the Austrian specimens ascribed by HÖRNES (1867, p. 265, Pl. 35, Figs 1-6) to *Cardita scabricosta*. SIEBER (1956, pp. 197-198, Pl. 1, Fig. 15) and STEININGER (1978, p. 344, Pl. 13, Figs 1-2) regarded SACCO's *vindobonensis* as a subspecies of LAMARCK's species *crassa*, whereas FRENEIX & al. (1987, pp. 422-423) considered that *crassa* and *vindobonensis* represent two distinct species. Investigation of EICHWALD's type specimen of *Venericardita laticosta* (LGU 3/193) has revealed that this species is, in fact, conspecific with SACCO's *vindobonensis*. In the present authors' opinion EICHWALD's *laticosta* and SACCO's *vindobonensis* should be treated as one species of the genus *Megacardita*, and, according to the priority rule, named *laticosta*.

Family **Cardiidae**

The systematic arrangement of cockles applied here follows POPOV (1977).

- 240** *Europicardium multicostatum* (BROCCHI, 1814)
 = *Trachycardium multicostatum* var. *miorotundatum* SACCO, 1899

The taxon *Europicardium* (with *Cardium multicostatum* as the type species) proposed by POPOV

(1977, p. 44) as a new subgenus of *Bucardium* GRAY, 1899, was later raised by the same author to generic level (POPOV in NEVESSKAJA & al. 1993, p. 213).

- 242** *Laevicardium* (*Laevicardium*) *baranovense* (HILBER, 1822)
 = *Cardium dingdense* LEHMANN, 1892
 = *Cardium* (*Laevicardium*) *pantecolpatum* COSSMANN & PEYROT, 1912
 = *Cardium* (*Trachycardium*) *rybnicense* FRIEDBERG, 1934
 = *Laevicardium antwerpiense* GLIBERT, 1945

The name *baranovense* was proposed by HILBER (1882, p. 13, Pl. 1, Figs 34-35) for specimens preserved as internal moulds. Specimens showing both internal and external shell characters have been recently found in Zaretshany, the West Ukraine (NEVESSKAJA & al. 1993, Pl. 53, Fig. 8, specimen PIN 1467/2225). Their surface sculpture is sufficiently well preserved to recognize these forms confidently as being conspecific with LEHMANN's species *dingdense*.

243-251 The revision of *Acanthocardia* was carried out by STUDENCKA & POPOV (1996). Nine species from the Middle Miocene Paratethyan strata were described, of which two (*allae* and *antonihoffmani*) were established as new.

- 244** *Acanthocardia* (*Acanthocardia*) *andrusovi* (SOKOLOV, 1899)
 = *Cardium platowi* BOGATSCHEW, 1905
- 246** *Acanthocardia* (*Acanthocardia*) *brocchii* (MAYER, 1866)
 = *Cardium hispidum* EICHWALD, 1830
 = *Cardium praeachinatum* HILBER, 1882
 = *Cardium pseudoturonicum* MIKHAILOVSKY, 1903

- 247** *Acanthocardia* (*Acanthocardia*) *centumpania* (ANDRUSSOW, 1911)
 = *Cardium impar* ZHIZHCENKO, 1936

- 248** *Acanthocardia* (*Acanthocardia*) *paucicostata* (SOWERBY, 1836)
 = *Cardium clavatum* HILBER, 1879
 = *Cardium aculeatum* var. *perrugosa* FONTANNES, 1879
 = *Cardium turonicum* var. *grundense* IVOLAS & PEYROT, 1900

= *Cardium andrussovi* var. *tulskajensis*
PAVLINOVA-ILJINA, 1957

- 247** *Acanthocardia (Acanthocardia) turonica*
(HÖRNES, 1861)
= *Cardium barrandei* IVOLAS & PEYROT, 1900
= *Cardium schafferi* KAUTSKY, 1925

255 PARAMONOVA (1971, p. 147) proposed *Obsoletiforma* as a typically Sarmatian genus, though she listed a few species from both Buglovian and Veselanian beds (the uppermost Badenian and Konkian strata, respectively). Specimens of *O. obsoleta* and *O. kokkupica* found in the Lower Badenian deposits are therefore the oldest known representatives of *Obsoletiforma*.

- 257** *Parvicardium? brykense*
GONTSHAROVA & ZHGENTI, 1989

This species is tentatively attributed to *Parvicardium* because of its shell outline, surface sculpture, hinge construction and microstructure, which approach *brykense* to representatives of the family Lymnocypridae.

- 258** *Parvicardium holubicense* (HILBER, 1882)
emend. FRIEDBERG (1934)
= *Cardium hilberi* ZHIZHCHEENKO, 1936
- 260** *Parvicardium michelotti* (DESHAYES, 1850)
= *Cardium hispidiforme* DAVIDASCHVILI, 1932
= *Cardium induratum* ZHIZHCHEENKO, 1936
- 263** *Parvicardium scabrum* (PHILIPPI, 1844)
= *Cardium scyloiticum* SOKOLOV, 1899
= *Cardium (Parvicardium) liverovskayae*
MERKLIN, 1950

267 The taxon *Discors* DESHAYES, 1858 is here considered as being not a subgenus of *Nemocardium* MEEK, 1876, but a separate genus characterized by its fragile shell being more oval in outline, with oblique secondary striae crossing the ribs of the anterior slope.

Family Mesodesmatidae

- 284** *Ervilia podolica* (EICHWALD, 1830)
= *Crassatella dissita* EICHWALD, 1830
- 285** *Ervilia pusilla* (PHILIPPI, 1836)

= *Ervilia leptotaecha* ZHIZHCHEENKO, 1936
= *Ervilia miopusilla* BOGSCH, 1937

Family Cultellidae

289-291 SCHUMACHER's original diagnosis of *Cultellus* is different from that given by KEEN (*in* MOORE 1969, p. N611). The hinge of the Mioocene species of *Cultellus* listed here consists of two cardinal teeth in the right valve and three cardinals in the left one, the medial of which being almost bifurcated, and it corresponds to the tooth formula given by SCHUMACHER (1817, pp. 22-23).

- 290** *Cultellus (Cultellus) papyraceus*
REUSS, 1867
= *Cultellus scaphoides* ZHIZHCHEENKO, 1934
= *Cultellus papyraceus areni* KRACH, 1968

Family Tellinidae

The systematic arrangement of the subfamily Tellininae is here adopted after GLIBERT & VAN DE POEL (1967, pp. 88-112). Consequently, only the forms having completely developed anterior and posterior lateral teeth are here assigned to the genus *Tellina* LINNAEUS, 1758. Apart from *Tellina*, GLIBERT & VAN DE POEL postulated also generic separation of *Arcopagia* BROWN, 1827, *Angulus* MEGERLÉ VON MÜHLFELD, 1811, and *Quadrans* BERTIN, 1878.

Family Donacidae

- 315** *Donax (Paradonax) tarchanensis*
BAJARUNAS, 1910
= *Donax sultanensis* BAJARUNAS, 1910
= *Donax bajarunasi* ANDRUSSOW, 1917
= *Donax nathjurus* GATUEV *in*
DAVIDASCHVILI, 1932
= *Donax bajarunasi* var. *abbreviatus*
ZHIZHCHEENKO, 1936
= *Donax (Paradonax) intermedia*
of STRACHIMIROV (1960),
non HÖRNES, 1859
- 316** *Donax (Paradonax) transversa*
DESHAYES, 1830
= *Donax gibbosula* MAYER, 1859

Family **Solecurtidae****329** *Pharus saucatsensis*
(DES MOULINS, 1871)

The specimens of this species recorded in the Miocene Paratethyan strata were, following HÖRNES (1867, pp. 17-18, Pl. 1, Figs 15a-b), referred to LINNAEUS' species *legumen* (BAGDASARIAN 1965, pp. 86-87, Pl. 2, Figs 16a, 16b; BAJARUNAS 1910, p. 248, Pl. 1, Fig. 31-32; GONTSHAROVA 1989, pp. 137-138, Pl. 23, Figs 14, 22; SIEBER 1955, p. 187). In 1871 DES MOULINS (*vide* COSSMANN & PEYROT 1909, pp. 155-158), when studying Recent and Miocene specimens, was able to demonstrate that they represent two distinct species, and to distinguish the fossil one as *saucatsensis*.

Family **Kelliellidae****334** *Alveinus nitidus* (REUSS, 1867)

The present authors agree with the statement of GLIBERT & VAN DE POEL (1966b, pp. 20, 22) that the hinge construction in REUSS' species *nitidus* is typical of *Alveinus* CONRAD, 1865. As demonstrated by STUDENCKA (1986, pp. 88-89), REUSS' *nitidus* cannot be treated as the type species of *Davidaschvilia* MERKLIN, 1950 (a subgenus of *Lutetia* DESHAYES, 1850) as considered by KEEN (*in* MOORE 1969, p. N653, Text-fig. E.130, 2a-b). Thus, ANDRUSSOW'S species *intermedia* remains the type species of *Davidaschvilia* as designated by MERKLIN (1950, pp. 69-71).

Family **Glossidae**

339, 340 The taxon *Miocardiopsis* GLIBERT, 1936 is here considered as being not a subgenus of *Glossus* POLI, 1795 but a separate genus. *Miocardiopsis* differs from *Glossus* in having the shell less convex, oval in outline, with the beaks not twisted and the umbonal part less inflated and with a sharp keel. *Miocardiopsis* is also distinguished from *Glossus* on the basis of the hinge details and the presence of concentric lamellae on the external surface.

Family **Veneridae****342** *Venus (Venus) tauroverrucosa* (SACCO, 1900)

- = *Venus cincta* of HÖRNES (1861),
non EICHWALD, 1830
- = *Chione (Clausina) biali* COSSMANN & PEYROT,
1912
- = *Venus cincta* var. *pseudoverrucosa*
FRIEDBERG, 1934
- = *Venus tauroverrucosa* var. *austriaca*
KAUTSKY, 1936
- = *Venus tauroverrucosa* var. *lamellosa*
KAUTSKY, 1936
- = *Venus fasciculata* of MERKLIN & NEVESSKAJA
(1955), non REUSS, 1859

344 *Venus (Ventricoloidea) nux*
(GMELIN, 1791)

- = *Cytherea multilamella* LAMARCK, 1818
- = *Venus marginata* EICHWALD, 1829

345 *Circomphalus subplicatus*
(D'ORBIGNY, 1847)

- = *Venus cincta* EICHWALD, 1850
- = *Venus (Chione) subplicata* var. *orientalis*
FRIEDBERG, 1934
- = *Venus (Circomphalus) plicata* var. *grundensis*
KAUTSKY, 1936
- = *Venus (Circomphalus) plicata* var. *rotundior*
KAUTSKY, 1936

Examination of the holotype of *Venus cincta* from EICHWALD'S collection housed in the Museum of the Historical Geology Department, University of St. Petersburg (LGU 3/239) indicates that this species belongs to *Circomphalus*. Moreover, it appears to be identical with D'ORBIGNY'S *subplicatus*, the latter name retaining priority.

352 *Pitar (Pitar) laskarevi* (SCHWETZ, 1912)

- = *Meretrix rudis* var. *taurica* ZHIZHENKO, 1936

353 *Pitar (Lamelliconcha) raulini*
(HÖRNES, 1861)

In the present authors' opinion, the species originally named *Cytherea raulini*, and attributed by SIEBER (1955, p. 183) to *Paradione* DALL, 1901 (treated as a subgenus of *Pitaria* RÖMER, 1875), should be included into *Lamelliconcha* DALL, 1902, a subgenus of *Pitar* RÖMER, 1857. This assignment is based on shell outline, surface sculpture, hinge structure and serration of the nymphas. Moreover, examination of the microstructure by POPOV indicates close relation of

HÖRNES' species to representatives of both *Pitar* and *Meretrix*, and differences between *raulini* and representatives of *Callista*.

354-356 The present authors agree with the statement of GLIBERT & VAN DE POEL (1966b, pp. 59-60) that the differences in the relative strength of the commarginal grooves covering the shells of *Callista* POLI, 1795, seem to be not sufficient for distinction of the subgenus *Costacallista* PALMER, 1929 from *Callista* s.s.

363 *Irus (Irus) irus* (LINNEAUS, 1758)
= *Venerupis pseudoirus* BAJARUNAS, 1910

360 *Gomphomarcia taurica* (BAJARUNAS, 1910)
= *Tapes tauricus* var. *extensis*
ZHIZHCHEENKO, 1934
= *Tapes erroneus* ZHIZHCHEENKO, 1936

372 The taxon *Polititapes* CHIAMENTI, 1900 is here considered as being not a synonym of *Venerupis* LAMARCK, 1818 but its subgenus, characterized by a shell ornamented with delicate commarginal lamellae or lines, while radial striae being either inconspicuous or not visible.

375 *Chamelea coturnix* (DUJARDIN, 1837)
= *Venus incrassata* of DU BOIS (1831),
non BROCCHI, 1814
= *Arthemis intermedia* EICHWALD, 1853

383 The taxon *Parvivenus* SACCO, 1900 is here considered as being not a synonym of *Timoclea* BRONN, 1827 but its subgenus, *Parvivenus*, unlike *Timoclea* s.s., has a surface sculpture consisting predominantly of concentric lines or lamellae, while radial striae are very weak and conspicuous only on the anterior and posterior slopes.

Family Corbulidae

395 *Corbula (Varicorbula) gibba* (OLIVI, 1792)
= *Corbula theodisca* HILBER, 1879
= *Corbula (Varicorbula) michalskii*
SOKOLOW, 1899

Family Pholadidae

410 *Barnea ujraticum* OSSIPOV, 1932
= *Barnea bulgarica* var. *tchokrakensis*
ZHIZHCHEENKO, 1937

= *Barnea (Anchomasa) cylindrica* ZHGENTI, 1966
= *Barnea (Anchomasa) minima* ZHGENTI, 1966

Family Cuspidariidae

427 *Cardiomya costellata* (DESHAYES, 1836)
= *Cuspidaria costellata* var. *lomnickii*
FRIEDBERG, 1934
= *Cuspidaria costellata* var. *zalescensis*
FRIEDBERG, 1934

PROBLEMS CONCERNING THE CORRELATION OF THE TARKHANIAN

The sedimentological and biostratigraphical differences between the Mediterranean and Paratethys, which constituted a chain of epicontinental sea-basins from the Western Alpine foredeep to the trans-Caspian area, resulted in the development of three distinct stage systems: the standard one for the Mediterranean and two others for the Central and Eastern Paratethys, respectively.

The Early/Middle Miocene boundary was originally defined (CITA & PREMOLI SILVA 1968) by the first appearance datum (FAD) of planktonic foraminifers of the genus *Praeorbulina*; at present (IACCARINO 1985) it is placed at the base of the *Praeorbulina glomerosa* Zone defined with the FAD of *Praeorbulina glomerosa*. The lower boundary of the Badenian regional stage in the Central Paratethys was also defined (PAPP & *al.* 1968, CÍCHA & SENEŠ 1968) by the FAD of *Praeorbulina*. By international agreement this bioevent is recognized as a distinct marker for reliable correlation of the base of the Langhian and Badenian stages. Moreover, the appearances of *Orbulina suturalis* in the Central Paratethys (upper part of the Lower Badenian) and the Mediterranean provinces (upper part of the Langhian) have been found to be relatively synchronous. However, neither *Praeorbulina* nor *Orbulina* occur in the Middle Miocene deposits of the Eastern Paratethys. That is why correlation of regional stage boundaries in the Central and Eastern Paratethys is highly controversial.

On the basis of published and unpublished data the present authors consider that the Kotsakhurian/Tarkhanian boundary falls within the Karpatian; the early Tarkhanian (the deposits of which contain abundant bivalve assemblages) may be equivalent to some part of the Karpatian (Text-fig. 1). The following arguments support this opinion:

(i) On the basis of calcareous nannofossils the base of the Tarkhanian can be correlated with the upper part of the Karpatian. In agreement with the original definition of MARTINI (1971), the time interval of the Karpatian is covered by the late NN4 and early NN5 nannozones. As reported by MARTINI & MÜLLER (1975), nannofossil assemblages, containing *Helicosphaera ampliaperta*, recorded

from the lower Karpatian strata in Austria and Moravia, belong to the terminal part of NN4; in the upper Karpatian strata, where *Helicosphaera ampliaperta* is missing, *Sphenolithus heteromorphus* becomes common and indicates the lowest part of NN5. The same distributional pattern of both *H. ampliaperta* and *S. heteromorphus* has been recognized in Hungary (NAGYMAROSY &

Ma	SERIES		Mediterranean stages	Planktonic foraminifer zones	Nannoplankton zones	Central Paratethys regional stages	Planktonic foraminifer zones	Benthonic foraminifer zones	Eastern Paratethys regional stages
11	UPPER	Tortonian	M13	NN 7-9	Pannonian	Sarmatian s.s.			Upper
			M12						
12	MIDDLE	Serravallian	M11	NN 6	Sarmatian s.s.				Middle
			M10						
13	MIDDLE	Serravallian	M9	NN 6	Sarmatian s.s.				Lower
			M8						
14	MIDDLE	Serravallian	M7	NN 6	Sarmatian s.s.				Lower
			M6						
15	MIDDLE	Langhian	M5b	NN 5	Sarmatian s.s.				Lower
			M5a						
16	MIDDLE	Langhian	M5b	NN 5	Sarmatian s.s.				Lower
			M5a						
17	LOWER	Burdigalian	M4b	NN 4	Sarmatian s.s.				Lower
			M4a						
18	LOWER	Burdigalian	M3	NN 3	Sarmatian s.s.				Lower
			M2						
19	LOWER	Burdigalian	M2	NN 3	Sarmatian s.s.				Lower
			M1						

Fig. 1. Correlation chart of Middle Miocene regional stages of the Central and Eastern Paratethys and Mediterranean Tethys; the chronology of the Mediterranean stages after BERGGREN & al. (1995); radiometric age of the stage and substage boundaries of the Central Paratethys after VASS & al. (1985, 1987) and STEININGER & al. (1987); ranking of the calcareous nannofossils biohorizons in the Central Paratethys after GOLOVINA & al. (1986), NAGYMAROSY & MÜLLER (1988), and STEININGER & al. (1987)

MÜLLER 1988), in the deposits beneath the overthrust of the Western Carpathians in Poland (OLSZEWSKA & GARECKA 1996), and in Romania (MARUNTEANU 1992).

The Tarkhanian hypostratotype section on the Kerch Peninsula is subdivided into three lithostratigraphic units. The occurrence of *H. ampliaperta* is documented in both the middle unit, represented by fossiliferous marls, and immediately above, in upper unit, the so-called Spirialis clays (NOSOVSKY & BOGDANOVICH 1984, KONENKOVA & BOGDANOVICH 1994). Moreover, the occurrence of the stratigraphically significant nannofossil assemblage recorded in the lowest upper unit of this section is limited to the lowest part of the NN5 nannozone (NOSOVSKY & *al.* 1976, NOSOVSKY & ANDREEVA-GRIGOROVICH 1987, KONENKOVA & BOGDANOVICH 1994). Likewise, the calcareous nannofossils recorded in the Tarkhanian of western Georgia (MINASHVILI 1981) are similar to the nannoflora assemblage found in the middle unit of the hypostratotype section of the Tarkhanian (MUZYLEV & GOLOVINA 1987). According to NOSOVSKY & ANDREEVA-GRIGOROVICH (1987), the middle unit of the Tarkhanian sequence on the Kerch Peninsula contains calcareous assemblage of the lowest part of NN5. This assemblage closely corresponds to the one from Varna (NE Bulgaria), as well as to those recognized in Namkashuri (western Georgia), and in Starokuvinsk (Precaucasus), but it is different from the one recorded from the Lower Badenian deposits in Poland. Thus, the distributional pattern of both *H. ampliaperta* and *S. heteromorphus* in the Tarkhanian hypostratotype sequence permits correlation of the lower-middle Tarkhanian with the Karpatian.

On the other hand, the upper unit of the stratotype section on the Kerch Peninsula yields a significantly impoverished nannofossil assemblage containing only non-age-diagnostic species (MUZYLEV & GOLOVINA 1987).

Summarizing, on the basis of the distributional pattern of *H. ampliaperta* and *S. heteromorphus* in the Central Paratethys (i.e. the last appearance datum of *H. ampliaperta* below the FAD of *S. heteromorphus*) the base of the Badenian stage falls within the standard zone NN5. Therefore the Karpatian/Badenian boundary does not coincide with the calcareous nannofossil zonal boundary (see NAGYMAROSY & MÜLLER 1988).

As mentioned above the base of both the Langhian and Badenian stages is linked biostratigraphically to the FAD of the *Praeorbulina*. The

recent study of the calcareous nannofossils from the Langhian stratotype section shows that the FAD of *S. heteromorphus* occurs below the FAD of *Praeorbulina* sp., while the last appearance datum (LAD) of *H. ampliaperta* occurs above the FAD of *Praeorbulina* sp. (FORNACIARI & RIO 1996). By using calcareous nannofossils the base of the Langhian stage in its stratotype section can only be approximated by the last common and continuous occurrence (LCO) of *H. ampliaperta* and by the acme end of *Discoaster deflandrei*, and it falls within the zone MNN4, established by FORNACIARI & *al.* (1996) in the Mediterranean region. In all Langhian sections studied by these authors they were able to demonstrate that *S. heteromorphus* becomes virtually absent or strongly reduced just above the LCO of *H. ampliaperta*.

The present authors are not in the position to assess whether the differences in the distributional pattern of *H. ampliaperta* and *S. heteromorphus* in the Paratethyan and Mediterranean provinces reflect distinct changes in the regional occurrence of these two species, or they result merely from the insufficient recognition of the Paratethyan nannofossil assemblages. Important, however, is the fact that distributional pattern of *H. ampliaperta* and *S. heteromorphus* is the same in both parts of the Paratethys.

(ii) A stratigraphically significant dinocyst assemblage has been investigated recently in the Tarkhanian deposits (just above the so-called Tarkhanian marls) exposed along the river Belaya (western Precaucasus). It comprises about 60 species and is characterized by a relatively high frequency of species belonging to the genera *Spiniferites* and *Operculodinium* (in total 50%), as well as to *Impagidinium* (ZAPOROZHETS, *personal communication* 1997). The presence of *Tuberculodinium vancampae* (index species of the Early Miocene Subzone VIIb according to the dinoflagellate zonation proposed by COSTA & DOWNIE 1979), *Hystrichosphaeropsis obscura* and *Lingulodinium machaerophorum* indicates that the age of the lowest upper Tarkhanian strata virtually coincides with Early/Middle Miocene boundary event. Assuming that this correlation is accurate, the lower-middle Tarkhanian is age-equivalent of the latest Burdigalian.

(iii) Various early Tarkhanian marine bivalve assemblages recorded by BAGDASARJAN (1970) and SAKHELACHVILI (1964) in Georgia, in Dzgha-

lian and Gorian beds, respectively; by MERKLIN & *al.* (1964) in the Kuvinian Beds in the Precaucasus; and by NOSOVSKY (1956) in the Tomakovian Beds in the southern Ukraine, include *Rzehakia dubiosa* and *Congeria nucleolus*, species typical of the underlying Kotsakhurian strata. A palaeo-environmentally significant bivalve fauna described by DAVIDASHVILI (1934), KVALIASHVILI (1962), POPOV & VORONINA (1983), and VORONINA & POPOV (1985) from the Kotsakhurian deposits from Kartli in Georgia is characterized by *Rzehakia dubiosa*, *Congeria subclaviformis*, *C. nucleolus*, *Eoprosodacna goriensis*, *E. kartlica*, *E. makae*, *Limnopappia caucasica*, *Cerastoderma ivericum*, *C. lacustre* and *Siliqua bavarica*. This assemblage is widespread in both the Western and Central Paratethys and is restricted to shallow-water brackish to freshwater facies originated during the late Ottnangian regression (CICHA & TEJKAL 1960, ČTYROKÝ 1968, 1987a, NAGYMAROSY 1981, SCHLICKUM & STRAUCH 1969). The stratigraphic record in both the western Alpine and western Carpathian foredeeps indicates the age of this Paratethyan endemic bivalve assemblage as latest Ottnangian, whereas the stratigraphic data from Slovak and Hungarian part of the Pannonian Basin (ČTYROKÝ 1987a, HÁMOR 1983, HORVÁTH & NAGYMAROSY 1978, KANTOROVÁ & *al.* 1967), and from South Dobrogea in Romania (TÁTÁRÁM & *al.* 1977), as well as from the Ukrainian part of the Carpathian Foredeep, indicate the earliest Karpatian (GORECKIJ 1956, KULCHYTSKY 1995). It is also important that the episode of exchange of endemic genera between Central and Eastern Paratethys took place within a very short time interval. In agreement with all these data, the brackish bivalves from the Kotsakhurian strata in the Eastern Paratethys may be coeval with those from the upper Ottnangian and/or the lower Karpatian deposits of the Central Paratethys.

(iv) On the basis of the radiometric dating and palaeomagnetic measurements the base of the Karpatian has been defined as 17.5 Ma (VASS & *al.* 1987), the base of the Tarkhanian as 17.1 Ma (PEVZNER & VANGENGHEIM *vide* STEININGER & *al.* 1987, p. 417), whereas the base of the Badenian as 16.5 Ma (VASS & *al.* 1985, 1987).

Unfortunately, the genera *Praeorbulina* and *Orbulina* are missing in the Eastern Paratethys and no diagnostic data on planktonic foraminifera are available for the Tarkhanian hypostratotype.

The assemblage recorded from the Kerch Peninsula key section comprises *Globigerina bulloides*, *G. praebulloides*, *G. tarchanensis*, *Globorotalia acostaensis*, *Gl. obesa*, *Gl. opima continuosa*, and *Planorotalia minutissima* (PISHVANOV in GONTSHAROVA 1989, pp. 6-12). This planktonic foraminifer assemblage was also noted from both Karpatian strata of the Ukraine (GRUZMAN & TROFIMOVICH 1995) and Lower Badenian of Poland (ŁUCZKOWSKA 1978). It allows the lower-middle Tarkhanian to be correlated either with the Lower Badenian substage, as was assumed by RÖGL & STEININGER (1984), STEININGER & *al.* (1985, 1990), JONES & SIMONS (1996), RÖGL (1996), or with the Karpatian stage (NOSOVSKY & BOGDANOVICH 1984, GONTSHAROVA 1989), and even with the Upper Badenian substage (PISHVANOVA 1970, BOBYLEV & PISHVANOVA 1979) of the Central Paratethys. Thus, the broad stratigraphic range of these globigerinid species makes correlation of the Tarkhanian strata difficult.

Nevertheless, the present authors are of the opinion that arguments i-iv indicate that the Kotsakhurian/Tarkhanian boundary is not isochronous either with the Karpatian/Badenian (RÖGL & STEININGER 1983, 1984, RÖGL 1996, STEININGER & *al.* 1985, 1990, JONES & SIMONS 1996) or with the Ottnangian /Karpatian (NEVESSKAJA & *al.* 1984, 1986, POPOV & VORONINA 1983, VORONINA & POPOV 1985, GONTSHAROVA 1989, POPOV & *al.* 1993) boundaries as assumed previously. This statement is crucial for the reconstruction of palaeobiogeographic picture of Europe in the Middle Miocene. The authors of the present paper are of the opinion that bivalve assemblages from the Lower Badenian of the Central Paratethys (mainly those from the Upper Lagenidae Zone) are contemporaneous with lower Chokrakian bivalve assemblages, and not with lower-middle Tarkhanian ones.

On the other hand, the age of the upper part of the Tarkhanian cannot be precisely defined because relevant data are not available. The present authors are not able to claim with confidence that the Karpatian/Badenian boundary is exactly equivalent to the Tarkhanian/Chokrakian boundary. Appropriate data for correlation of the upper boundary of the Early Badenian within the Central Paratethys with the upper boundary of the Chokrakian in the Eastern Paratethys are also missing. NEVESSKAJA & *al.* (1984, 1986) and MURATOV & NEVESSKAJA (1986 pp. 43-44) consider,

merely on the basis of hydroregime similarities in both basins and the presence of evaporites, that the base of the Karaganian presumably coincides with the base of the Middle Badenian (Wieli-czian) substage.

LANGHIAN MEDITERRANEAN TETHYS – PARATETHYS CONNECTIONS

Central Paratethys

The Early Badenian bivalve fauna under analysis, being the age-equivalent of the Langhian fauna from the Mediterranean Province, was derived from 8 localities (Text-fig. 2). These were chosen to ensure that bivalve assemblages from the largest possible area of the Central Paratethys were represented. Four of them, i.e. Mikulov, Małoszów, Târnene and Yasen are situated in Fore-Carpathian basins, the remaining four – Coștei, Várpalota, Steinabrunn, and Lăpugiu – are located in the Intra-Carpathian basins (detailed locality is shown above in the chapter *Provenances*). According to the biostratigraphical zonation based on foraminifera, the bivalve assemblages from Coștei (POPESCU 1987, RÖGL & BRANDSTÄTTER 1993) and Małoszów (GONERA & KULKA 1979) belong to the Lower Lagenidae Zone.

The stratigraphical position of the sandy successions in Mikulov (ČTYROKÝ 1987b), Lăpugiu (POPESCU 1987, RÖGL & BRANDSTÄTTER 1993), Várpalota (KÓKAY 1991), as well as in Târnene and Yasen (KOJUMDIEVA 1985), is determined as Upper Lagenidae Zone, whereas the deposits of Steinabrunn belong to the uppermost Upper Lagenidae and lowermost Spiroplectamina zones (RÖGL & BRANDSTÄTTER 1993) of Vienna Basin ecostratigraphy (*see* Text-fig. 1).

The total number of bivalve species recognized in the Lower Badenian sandy deposits is 343 (Table 1, columns 3-10 and 20). The very similar species composition of these 8 shallow-water assemblages coming from such distant parts of the Central Paratethys reflects active faunal interchange between fore- and intramontaine basins. The comparison of assemblages from the Lower and Upper Lagenidae zones (Table 1, columns 7 and 6, respectively) also indicates no pronounced modifications in species composition.

Additional data on bivalves from Intra-Carpathian basins are included in the recent study by DULAI (1996), showing that the assemblage from

Szob (northern Hungary) is characterized by a taxonomic diversity comparable – at generic level – to that of other Early Badenian assemblages. Apart from the freshwater species *Pisidium* (*P.*) *priscum*, the remaining 73 species recorded in Szob can be found within the total of 343 species listed (Table 1). Moreover, the taxonomic structure of the assemblage from Szob (expressed in percentages of particular subclasses) is similar to that of other Badenian bivalve assemblages from the sandy facies (*see* STUDENCKA & STUDENCKI 1988a, STUDENCKA 1994). This is expressed by the relatively low percentage of the subclass Pteriomorphia (23%), and the high percentage of the Heterodonta (75%), as compared to assemblages from the carbonate facies where the proportion of Pteriomorphia is relatively higher (37-42%), while that of the Heterodonta is relatively lower (53%) (STUDENCKA & STUDENCKI 1988a, STUDENCKA 1994).

Of the 343 species recorded from the Lower Badenian sandy deposits of the Central Paratethys, 162 species are reported also from the Middle Miocene of the Mediterranean Province (Table 1, column 44) and 207 species from the Middle Miocene of the Atlantic Province (Table 1, column 43). At least 132 species appear to be common to all three provinces in question. The absence from the Mediterranean Province of 77 species which are recorded in both the Lower Badenian of the Central Paratethys, as well as in the Middle Miocene of the Atlantic Province, presumably results from insufficient recognition of the Middle Miocene Mediterranean bivalves (there is no modern bivalve monograph concerning the whole area of Italy, Spain or any other Mediterranean country). Moreover, there are 76 species common to the Lower Badenian of the Central Paratethys and the Middle Miocene of the North Sea Basin (JANSSEN 1984, KAUTSKY 1925, NORDSIECK 1972, SORGENFREI 1958), of which 13 species, viz. *Nuculana* (*Jupiteria*) *pygmaea*, *Modiolula phaseolina*, *Flexopecten lilli*, *Erycina* (*Hemilepton*) *mionitida*, *Mioerycina coarctata*, *Montacuta substriata*, *Tellimya ferruginosa*, *Glans* (*Centrocardita*) *squamosa*, *Astarte* (*A.*) *waeli*, *Goodalia* (*G.*) *trangularis*, *Parvicardium scabrum*, *Clausinella scalaris*, and *Thracia* (*Th.*) *ventricosa* have not been reported hitherto from either the Atlantic or the West Mediterranean Province, albeit the occurrence of *Clausinella scalaris* and *Thracia* (*Th.*) *ventricosa* is documented in the Middle Miocene fauna of the East Mediterranean (ERÜNAL-ERENTÖZ 1958).

Thus, the presence of 135 species (38%) in common with both contemporaneous Atlantic and Mediterranean faunas, as well as 76 species (20%) in common with the North Sea Basin fauna indicate good connection of the Central Paratethys with the world ocean.

The majority of the bivalves known in the Lower Badenian were widespread, while the geographical distribution of 56 species was limited to the Paratethys Province. This group consists of 49 species, which appeared in the Early Badenian. Three species, namely *Mytilus* (*Crenomytilus*) *haidingeri*, *Crassostrea miocucullata*, and *Pitar* (*Lamelliconcha*) *raulini*, are also reported from the Eggenburgian of the Central Paratethys (SCHAFFER 1910), four others, viz. *Glycymeris* (*G.*) *obtusatus*, *Congerina* (*Andrussoviconcha*) *sandbergeri*, *Cardiocardita schwabenaui*, and *Paphia waldmanii waldmanii* have been found in the Karpatian deposits as well.

Of 49 species that make their first appearance in the Early Badenian, 15 species, namely *Barbatia pseudobarbata*, *Arcopsis helenae*, *Aequipecten lapugensis*, *Lucina kadievi*, *Erycina piai*, *Lepton palotense*, *Mysella modioliformis*, *Tellinomya fasciculata*, *Sportella palotensis*, *Glans transylvanica*, *Angulus* (*Peronea*) *poelsensis*, *A.* (*Peronidia*) *bipartitus bulharensis*, *Paphia waldmanii cserhatensis*, *Clausinella bulgarica* and *Pleurodesma gibbosa* are limited to the Early Badenian of the Central Paratethys; they constitute about 5% of the entire Early Badenian fauna. On the other hand, 34 others survived throughout the Badenian, and during the Late Badenian 9 of them entered the Eastern Paratethys. These species, viz. *Musculus conditus*, *Aequipecten diaphanus*, *Plicatiforma praeplicata*, *Obsoletiforma obsoleta*, *O. kokkupica*, *Parvicardium subhispidum*, *Maetra* (*Sarmati-maetra*) *eichwaldii*, *Tellina* (*Laciolina*) *pretiosa*, and *Timoclea* (*T.*) *sobieskii*, are recorded from a number of Konkian (age-equivalent of Late Badenian) localities.

The geological record indicates that the Early Badenian Sea communicated with the Mediterranean through the passage between the Dinarids and the Alps, named the Transtethyan Trench "Corridor" (BISTRICIC & JENKO 1985, RIJAVEC 1985). During the Early Badenian, the link between the Mediterranean area and the Pannonian part of the Central Paratethys was so broad that POPESCU & *al.* (1995, p. 4, Fig. 3) used the

standard stages to define the age of deposits in this realm. In addition, the geological record documents a broad connection between the Moravian part of the Carpathian Foredeep and the Vienna Basin during the Early Badenian (ČTYRŮKY 1992, SAUER & *al.* 1992).

Towards the East Mediterranean

Close inspection of the Early Badenian bivalve fauna reveals the introduction into the Central Paratethys of both oriental and Indo-Pacific elements. The oriental fauna is represented by the *Flexopecten scissa* group, reported from the Middle Miocene of Syria and Mesopotamia (ROGER 1939). In the palaeogeographic reconstructions presented by RÖGL & STEININGER (1984) *Flexopecten scissa* is one of the important elements proving the connection between the East Mediterranean and the Paratethys. These authors considered, however, that *Fl. scissa* populated the Central Paratethys in the Late Badenian, whereas its presence in the Central Paratethys is documented in Lower Badenian localities of Bulgaria (KOJUMDIEVA 1960), the Ukraine (KAZAKOVA 1952), and Poland (KRACH 1957, 1967, 1979; STUDENCKA & STUDENCKI 1988a). Indeed, specimens of *Flexopecten scissa* are very common in the Upper Badenian deposits of Poland (JAKUBOWSKI & MUSIAŁ 1979; KRACH 1957, 1967, 1979; WOŹNY 1962), the Ukraine (FRIEDBERG 1932, 1936, HILBER 1882, KAZAKOVA 1952), Romanian Moldova (IONESI 1968, NICORICI 1977) and Bulgaria (KOJUMDIEVA 1960). In contrast, this species is extremely poorly represented in the Upper Badenian of Hungary (CSEPREGHY-MEZNERICS 1960) and Slovakia (the CUB collection). There are apparently no records of the *Flexopecten* group in the Badenian of Austria, in the Langhian of northern Italy and in the Eastern Paratethys.

The Indo-Pacific elements in the Central Paratethys are exemplified by the large foraminifera *Amphistegina*, *Heterostegina*, *Borelis*, and *Sphaerogypsina* (see RÖGL & BRANDSTÄTTER 1993), decapoda (MÜLLER 1984), the gastropod *Tritonoharpa* DALL (BAŁUK 1997), the chiton *Cryptoplax* DE BLAINVILLE (BAŁUK 1971, ŠULC 1936), the inarticulate brachiopod *Discinisca* DALL (RADWAŃSKA & RADWAŃSKI 1984), as well as by the seagrass-associated macrobenthic community (HOFFMAN 1979). Some of them, e.g.

Tritonoharpa and *Discinisca*, have not been recorded in the Middle Miocene deposits of the Mediterranean Province. On the other hand, the stratigraphical distribution of the gastropod turrid genus *Spirotropis* SARS documents the faunal migration from the Central Paratethys towards the East Mediterranean (JANSSEN 1993). Moreover, 30 species out of 42 reported from the Middle Miocene fauna of eastern Anatolia (ERÜNAL-ERENTÖZ 1958) are also present in the Early Badenian fauna of the Central Paratethys. These include *Amusium cristatum*, *Propeamusium duodecylamellatum*, *Flabellipecten besse-ri*, *Fl. nodosiformis*, *Fl. solarium*, *Aequipecten malvinae* and *Ae. scabrellus*.

Taking into account the geographical and stratigraphical distribution of the taxa mentioned above, it seems very likely that in the Early Badenian the Central Paratethys was connected with the West Mediterranean not only through the western Transtethyan Trench "Corridor", but also with the East Mediterranean Basin through a southern passage. The existence of the latter has, unfortunately, no geological support. It is, then, impossible to indicate the precise location of the southern passage due to later tectonic activity and rotation of Greece (WESTPHAL & al. 1991).

The above hypothesis concerning two connections of the Central Paratethys with the Mediterranean (STUDENCKA & al. 1995) agrees, though only in part, with the opinion of VOICU (1985) who suggested that the Early Badenian transgression, strongly influenced by Indo-Pacific waters, flooded only the eastern part of the Central Paratethys, i.e. the Carpathian Foredeep and the Transylvania and Oraşia basins. According to VOICU (1985), the southern corridor was the only connection between the Central Paratethys and the world ocean and, consequently, migration in the Early Badenian Sea, occurred from East to West.

Eastern Paratethys

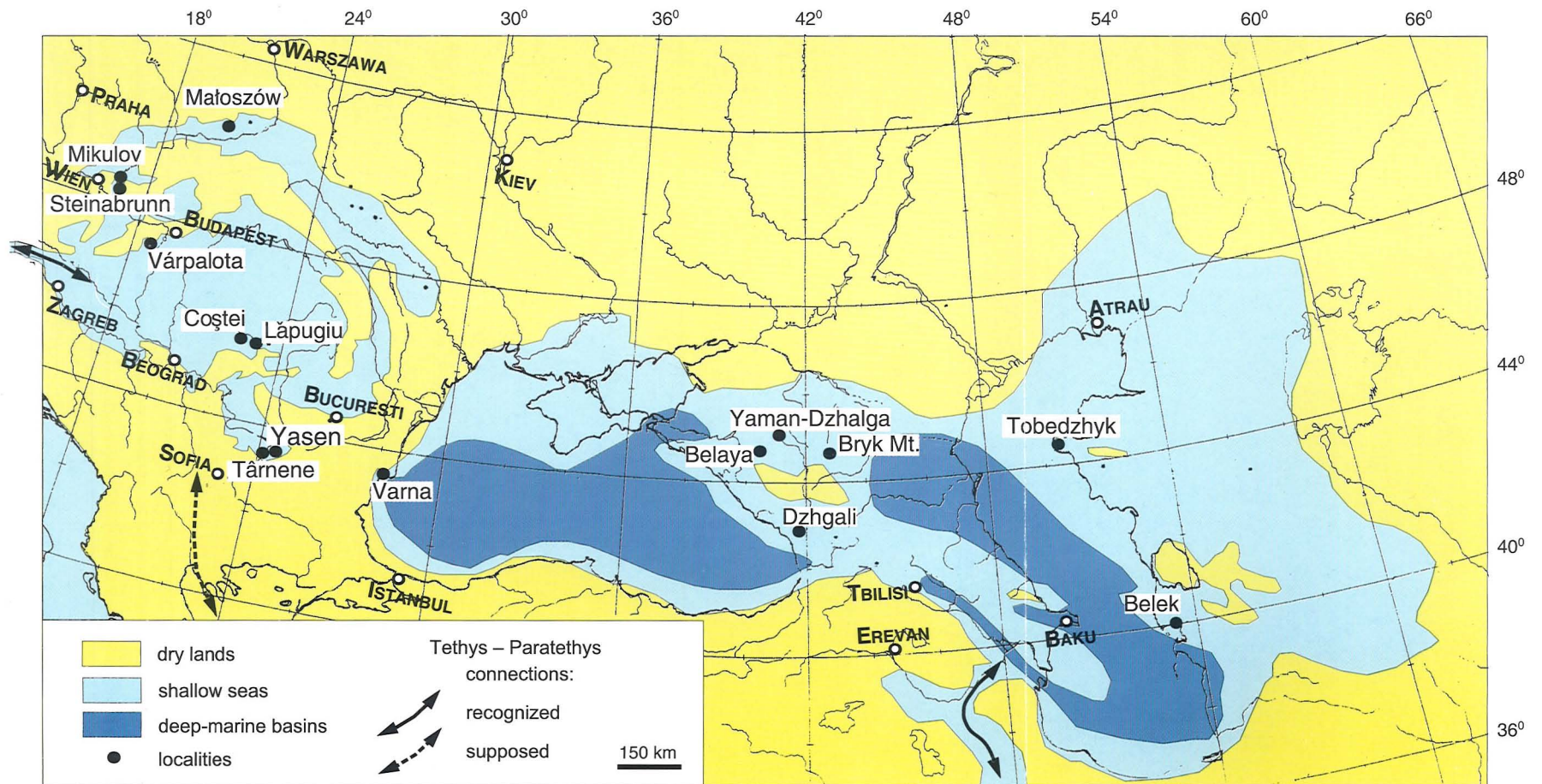
After revision of the original collections of Chokrakian material, it appeared that the total Chokrakian fauna comprises 71 species (Table 1, columns 11-18). This fauna consists largely of remnants of the Eastern Paratethys Tarkhanian fauna. Of 56 species marked T in Table 1 (column 11), 50 survived throughout the Tarkhanian, while 6 were restricted to the early Tarkhanian and re-invaded the Eastern Paratethys in the

early Chokrakian. The latter group includes *Anadara diluvii*, *Cardites partschii*, *Lutraria lutraria*, *L. sanna*, *Circomphalus subplicatus* and *Pelecycora islandicoides*. In addition, 5 other open-marine species, namely *Limaria* (*Limatulella*) *loscombi*, *Cubitostrea digitalina*, *Felaniella trigonula*, *Dosinia* (*Asa*) *lupinus*, and *Clausinella basteroti*, invaded the Eastern Paratethys to enrich the early Chokrakian fauna. All of the Chokrakian migrant species have also been reported from the Middle Miocene of the Atlantic, Mediterranean and Central Paratethys.

The third group of Chokrakian bivalve species consists of 9 endemic taxa. The ancestors of 5 Chokrakian endemic species, viz. *Aequipecten varnensis*, *Parvicardium?* *brykense*, *Ervilia praepodolica*, *E. megalodon* and *Barnea praeustjurtensis*, have definitely been identified in the former Tarkhanian fauna (BAGDASARJAN 1965, 1974, GOTSHAROVA 1989), whereas *Angulus* (*Fabulina*) *fuchsi* and *Thracia tschokrakensis* suddenly appear without having any ancestors in the Tarkhanian fauna. The immediate ancestors of *Donax* (*Paradonax*) *tarchanensis* and *Pitar* (*P.*) *laskarevi* have also not been identified.

Thus, the early Chokrakian fauna is characterized by the distinctive tripartite nature of its taxonomic composition, with regard to the origin of particular species: group 1 comprising Tarkhanian remnant species, group 2 of open-marine Chokrakian migrants, and group 3 of endemic species which originated in the early Chokrakian. The distribution of group 2 within the Eastern Paratethys is especially revealing. The bivalve fauna from the westernmost part of the basin (Black Sea coast of Bulgaria) consists of 36 species (Table 1, column 12; STRACHIMIROV 1960) none of them being a migrant and only 5 being endemics. In the assemblage from the Sinop Peninsula (Turkey) presented by ÖZSAYAR (1977), who described and illustrated 8 species, there are no migrant species and only a single endemic, *Pitar* (*P.*) *laskarevi*, is reported. The fauna of the Kerch Peninsula in the Crimea (GONTSHAROVA 1989) includes 43 bivalve species with 2 migrants and 2 endemics, whereas the most diversified Chokrakian fauna recorded in the Precaucasian area comprises 52 species (Table 1, columns 13-15; GONTSHAROVA 1989), of which 4 represent migrants and 5 endemics. In the Georgian fauna 45 species are identified (Table 1, column 16; BAGDASARJAN 1965, GONTSHAROVA 1989): these include 3 migrants and 7 endemics.

Early Badenian – Chokrakian (age-equivalent of the Langhian) palaeogeography of the Central and Eastern Paratethys



The map simplified and compiled after HÁMOR (1988, Map 3), MOLYAVKO & KHAIN (1962, Map 77), GONTSHAROVA & SHCHERBA (1997, Fig. 2)

The total Transcaspian bivalve fauna considered in this study includes 42 species (Table 1, columns 17-18, GONTSHAROVA 1989) with the exception, however, of the bivalves from Azerbaijan, from where only a list of species is available without either descriptions or illustrations (ALI-ZADE & *al.* 1980). In spite of the incomplete data on the Transcaspian fauna, it seems to be clearly characterized by a high proportion of migrants. Of the 42 species, 9 represent migrants and 7 endemics.

On the basis of the above observations, it is possible to indicate the direction from which euhaline species invaded the Eastern Paratethys. The occurrence of 7 migrant species is limited to the Transcaspian area, 5 of them (*Anadara diluvii*, *Cardites partschi*, *Lutraria sanna*, *Pelecycora islandicoides* and *Clausinella basteroti*) being recorded only in one exposure – Belek (Table 1, column 18, Fig. 1). The remaining 4 out of a total of 11 migrant species were more widespread in the early Chokrakian Sea, but they have never been recorded west of the Kerch Peninsula. This distribution of Chokrakian migrant species clearly indicates that the Eastern Paratethys must have been connected with the world ocean only in its south-eastern part. This conclusion is supported by gastropod data (ILJINA 1993, 1995) indicating that the Chokrakian fauna changed gradually, longitudinally, from the most diversified eastern assemblages rich in migrants to the most impoverished ones, located in the more westerly situated localities of the Ukraine. Furthermore, the echinoids, which have been reported only from eastern Georgia (BAGDASARIAN 1965) and western Turkmenistan (NEVESSKAJA & *al.* 1986), also document marine connections through a south-eastern passage by way of the Aker-Mid-Araks and Fore-Talysh depressions towards the Turkey basins (ALI-ZADE & *al.* 1980). This passage, named the Middle Araks Straight, temporarily permitted the inflow of normal salinity water and the migration of the marine fauna into the Eastern Paratethys during the Tarkhanian-early Chokrakian (NEVESSKAJA & *al.* 1986, GONTSHAROVA 1989, ILJINA 1995, GONTSHAROVA & SHCHERBA 1997). Palaeontological data from Northern Iran (STÖCKIN & SETUDEHNIA 1971, 1972 *vide* JONES & SIMMONS 1996) also seem to confirm the temporal existence of this seaway.

Beginning with the late Chokrakian, this open oceanic connection closed and semi-marine

conditions prevailed in the Eastern Paratethys (NEVESSKAJA & *al.* 1984, 1986, GONTSHAROVA 1989, ILJINA 1993). The diversity of the molluscan faunas was drastically reduced. The upper Chokrakian yields only 6 bivalve species, namely *Lutetia (D.) intermedia*, *Ervilia praepodolica*, *Donax (P.) tarchanensis*, *Abra parabilis*, *Barnea praeustjurtensis* and *B. ujraticamica*, all of them being endemic for the Eastern Paratethys. However, it should be stressed that *L. intermedia*, *A. parabilis* and *B. ujraticamica* are common to both the Tarkhanian and Chokrakian faunas, while the occurrence of the remaining 3 is restricted to the Chokrakian fauna.

The question of the home area of the early Chokrakian open-marine migrants remains still unsolved. Finding an answer to this question is hampered by the fact that during the Langhian both the Mediterranean and the Indo-West Pacific parts of the Tethys were connected (BERNASCONI & ROBBA 1982, RÖGL & STEININGER 1984) by way of the Arabian Gulf and Iran (ALI & CHERIF 1987) and/or by the Mesopotamian Trough (DEMARCO 1984). All of the Chokrakian migrant species show wide geographic distribution in the European Neogene bioprovinces of RÖGL & STEININGER (1984). Of 11 migrant species, 5 are also documented in the Middle Miocene fauna of south-east Anatolia in the East Mediterranean (ERÜNAL-ERENTÖZ 1958). In addition, two Chokrakian endemics, *Donax (P.) tarchanensis* and *Thracia tschokrakensis*, show definite Mediterranean affinities at the generic level. Two other endemics, *Angulus (Fabulina) fuchsi* and *Pitar (P.) laskarevi* show rather Atlantic affinities at the subgeneric level, and it is possible that *Pitar (P.) nitidula* (D'ORBIGNY), recorded in the Lower Miocene of France, is the most probable ancestor of *P. (P.) laskarevi*.

From the above data it can be concluded that, in the Chokrakian, the Eastern Paratethys became connected with the East Mediterranean (STUDENCKA & *al.* 1995, GONTSHAROVA & SHCHERBA 1997) rather than only with the Indo-Pacific regions of the Tethys (NEVESSKAJA & *al.* 1987; GONTSHAROVA 1989, p. 151). The East Mediterranean connection was also proposed by BEN MOUSSA & DEMARCO (1992) but, on the basis of the map published by GONTSHAROVA (1989), those authors located it in Thracia, in the south-western part of the Eastern Paratethys. This erroneous interpretation was probably due to the unfortunate

choice of time slices for the palaeogeographical maps of the Paratethys and adjacent basin that were prepared by NEVESSKAJA & *al.* (1984, p. 92, 1987, p. 338, Fig. 1C), and GONTSHAROVA (1989, p. 51, Fig. 4). These maps show a combination of data from the Chokrakian and Tarkhanian, i.e. from the time span encompassing periods of connection and disconnection of the Central and Eastern Paratethys. In the present authors' opinion, the absence of the Chokrakian migrant species in the Bulgarian fauna as well as the extremely impoverished Turkish (ÖZSAYAR 1977) and southern Ukrainian bivalve faunas (GONTSHAROVA 1989), provide evidence that the connection proposed by BEN MOUSSA & DEMARCQ (1992) is highly improbable. Moreover, the gastropod fauna accompanying the early Chokrakian transgression yields Indo-Pacific elements (ILJINA 1993, 1995). Thus, joint molluscan evidence indicates that in the Chokrakian the Eastern Paratethys was intimately linked with the East Mediterranean and remained under Indo-Pacific influences, but the seaway towards the Central Paratethys became closed.

Disconnection of Central and Eastern Paratethys

The above discussion indicates that in Early Badenian – Chokrakian time both the Central and Eastern Paratethys were connected by separate seaways with the Mediterranean, from where bivalve fauna immigrated into both basins independently. In this respect, the similarity of species composition of the Early Badenian and Chokrakian faunas cannot be considered as indicative for the connection of the Central with the Eastern Paratethys. It seems necessary to emphasize that, in defining connections and separations of the Central and Eastern Paratethys basins, it is not the number of species common to Lower Badenian and Chokrakian faunas which is indicative for connection/disconnection, but the time they arrived in the Eastern Paratethys.

The comparison of the species composition of Lower Badenian and Chokrakian faunas shows the occurrence of 37 species common to both parts of the Paratethys. However, 25 of them, being Tarkhanian survivors (along with 25 other species, cf. Table 1, column 11), populated the Eastern Paratethys earlier than in the Chokrakian, i.e. in the

Tarkhanian, when the Eastern Paratethys was broadly connected with the Central Paratethys (NEVESSKAJA & *al.* 1979, 1984, 1986, 1987, GONTSHAROVA 1989). On the other hand, the biogeographical pattern of the remaining 11 species which populated the Eastern Paratethys in the early Chokrakian proves no communication between Central and Eastern Paratethys at that time.

Particularly meaningful is the comparison of two adjacent bivalve assemblages from Bulgaria, one assigned to the Central, and the other to the Eastern Paratethys. The Lower Badenian assemblage from the Lom Depression consists of 135 species (Table 1, columns 9-10, POPOV & *al.* 1996) while the Chokrakian one in the vicinity of Varna contains only 36 species (Table 1, column 12), of which 8 are common with Lom but all are inherited from older Tarkhanian fauna. This dissimilarity of the bivalve assemblages strongly supports the disconnection of the Central and Eastern Paratethys.

The only species of Paratethyan origin common to both parts of the Paratethys is *Congerina (Andrusoviconcha) sandbergeri*. However, in view of the fact that this species very closely resembles its probable ancestor, *C. (A.) amygdaloides* DUNKER, and that it is also known from Karpatian strata of the Central Paratethys, it is difficult to determine the exact time of its migration into the Eastern Paratethys.

Thus, apart from *Congerina (A.) sandbergeri*, none of the bivalve species appears to be restricted to both Lower Badenian and Chokrakian faunas. The Eastern Paratethyan fauna, consisting of 71 species, was characterized by the presence of 28 endemic species, while in the Early Badenian the occurrence of 56 species out of total number of 343 recorded in the Lower Badenian sandy facies was limited to the Central Paratethys.

Calcareous nannofossil data also support the evidence based on bivalves that during Early Badenian – Chokrakian time the connection between both parts of the Paratethys ceased to be operative. The Lower Badenian deposits of Moldova, in the eastern part of the Central Paratethys, contain nannofossils that enable easy identification of the NN5 zone by means of a normal assemblage which is also documented in numerous sections within the Fore-Carpathian basin (GOLOVINA & *al.* 1986, MUZYLEV & GOLOVINA 1987), whereas the Chokrakian nannofossils are strongly impoverished, both with respect to species

diversity and abundance of individuals (MUZY-LEV & GOLOVINA 1987).

The disconnection of the Central and Eastern Paratethys is also supported by the distribution of two large foraminifera, *Amphistegina* and *Heterostegina*, both of Indo-Pacific affinities. They are very common and abundant in the Lower Badenian strata, but completely absent in the Chokrakian.

The results presented above are in strong opposition with the view of STEININGER & RÖGL (1979), RÖGL & STEININGER (1983, 1984), STEININGER & al. (1985) that in the Early Badenian open seaways existed between the Mediterranean, both parts of the Paratethys and the Indo-Pacific. Furthermore, the geological data from both South Dobrogea in Romania (TATÁRAM & al. 1977) and Moldova (GONTSHAROVA & ILJINA 1997) also confirm that there was no communication between the Central and Eastern Paratethys in the Lower Badenian (age-equivalent of the Langhian).

EARLY SERRAVALLIAN MEDITERRANEAN TETHYS – PARATETHYS CONNECTIONS

Central Paratethys

The number of bivalve species recorded in the Upper Badenian sandy deposits totals 316. The majority of them, i.e. 274 species, have also been reported from the Lower Badenian deposits. This number includes 39 species endemic to the Paratethys. On the other hand, 50 species of wide geographical distribution recorded in the Early Badenian of the Central Paratethys are absent from the Late Badenian fauna. The Late Badenian fauna contains 26 other species distributed in several bioprovinces which first appeared at this time in the Central Paratethys.

The comparison of Early to Late Badenian faunas shows some minor though significant changes in their composition. The number of families decreases from 60 to 59 (representatives of Mallettiidae are missing from the Late Badenian). Moreover, in the majority of families a decrease in the number of species and, in two cases, a decrease in number of genera is observed: in the Pectinidae from 17 to 15, and in the Lucinidae from 17 to 14. By contrast, in the following families the number of species increases by one: in Nuculidae: *Nucula (Lamellinucula) cromata*;

Thyasiridae: *Thyasira (Th.) ferruginea*; Mytilidae: no records of *Mytilus (Crenomytilus) haidingeri* and *Brachidontes tenuiradiatus* but the appearance of *Brachidontes biali*, *Mytilus (M.) hoernesianus* (known from both Eggenburgian and Ottnangian, but not recorded from the Lower Badenian), and *Musculus sarmaticus*; Kelliidae: *Lasaeokellya cestosensis*; Astartidae: *Astarte radiata*; Crassatellidae: *Crassatella (Lendina) sp*; Cardiidae: no records of *Cerastoderma arcella arcella* and *Discors aquitanicus*, but the appearance of *Acanthocardia (A.) allae*, *A. (A.) brocchii*, and *A. (A.) ritzingense*; Mesodesmatidae: *Ervilia podolica* and *E. trigonula*; Donacidae: *Donax (Paradonax) dentiger*; Semellidae: no records of *Abra (Syndosmya) cytheraeiformis*, but the appearance of *A. (S.) alba scythica* and *A. (S.) reflexa*; Kelliellidae: *Kelliella barbara*; Pholadidae: *Pholadidea loscombiana*; Thraciidae: no records of *Thracia phaseolina* and *Th. papyracea papyracea*, but the appearance of *Th. bellardi*, *Th. papyracea sandeciana*, and *Astheothesaurus desmoulini*; and Cuspidariidae: *Cardiomya costellata*.

The above list of species that have been recorded in the Central Paratethys for the first time in the Late Badenian includes forms, the occurrence of which is limited to the Paratethys, as well as those widely distributed in contemporaneous deposits of the Atlantic, Mediterranean, and North Sea provinces (Table 1, columns 43, 44, respectively; GLIBERT 1945). The first group contains 17 species, of which the following 6 are limited to the Central Paratethys: *Pseudolepton bayeri*, *Neoromya (?Orobitella) roztoczensis*, *Acanthocardia (A.) allae*, *A. (A.) ritzingense*, *Kelliella barbara*, and *Thracia papyracea sandeciana*, while an additional 11 endemic species have also been reported from the Konkian of the Eastern Paratethys: *Musculus sarmaticus*, *Palliolium bitneri*, *Ervilia podolica*, *E. trigonula*, *Donax (Paradonax) dentiger*, *Abra (Syndosmya) abra scythica*, *A. (S.) reflexa*, *Gomphomarcia secunda*, *Venerupis (Politiitapes) modesta*, *V. (P.) vitaliana*, and *Timoclea (Parvivenus) konkensis*.

Of 316 Late Badenian species, 190 are also recorded from the Middle Miocene of the Atlantic Province, 134 – in the Mediterranean Province while 114 species are common to all three provinces. Moreover, of 64 species known from the Middle Miocene of the North Sea Basin, as many as 54 are recorded in the Late Badenian fauna of the Central Paratethys.

All these figures evidence broad connection of the Central Paratethys with the world ocean. The problem is, however, to identify the location of the potential corridor linking the Central Paratethys with the Mediterranean. The geological data definitely show the closure of both the western connection with the Mediterranean, which remained open during the Early Badenian (BISTRICIC & JENKO 1985, RIJAVEC 1985, MASSARI 1990) as well as the connection of the Vienna Basin with the Fore-Carpathian Depression: the marine sedimentation in the area of Moravia came to end in the Early Badenian (ČTYROKÝ 1992, SAUER & *al.* 1992).

As mentioned above, 26 species common to the Mediterranean Province, Atlantic Province and North Sea Basin appeared in the Central Paratethys together with the Late Badenian transgression. This fact, along with the distinct Atlantic – Mediterranean affinity (at the generic level) of the new evolved species, prove that the connection of the Central Paratethys with the Mediterranean was still in existence. It is additionally confirmed by the decapods (MÜLLER 1996), brachiopods (BITTNER 1990), and holoplanktonic gastropods among which species common to the Central Paratethys and North Sea Basin have been recorded (JANSSEN & ZORN 1993). At the same time, the presence of the inarticulate brachiopod genus *Discinisca* DALL (RADWAŃSKA & RADWAŃSKI 1984), and the chiton genus *Cryptoplax* DE BLAINVILLE (STUDENCKA & STUDENCKI 1988b) in the Late Badenian of the western Ukraine indicate that Indo-Pacific influence was still active.

In conclusion, the present authors are of the opinion that, after the closure of the western passage – the Transtethyan Trench “Corridor” – the other, East Mediterranean connection was still operative. Its probable location in Thracia is indicated by the deposits identified west of Stambul, the age of which is equivalent to Late Badenian – Konkian (LÜTTIG & STEFFENS 1976, *vide* STEININGER & *al.* 1985, p. 36, RÜCKERT-ÜLKUMEN & *al.* 1993). It may be supposed that the Late Badenian Sea communicated with the East Mediterranean through the Axios (Vardar) Trench because the upper Burdigalian to Langhian or Serravallian (“Tortonian”) marine deposits have been recorded in the lower Axios valley (CHRISTODOULOU 1965, *vide* KOUFOS 1990).

The statement about the direct connection of the Central Paratethys with the East Mediterranean is distinctly different from the view of RÖGL

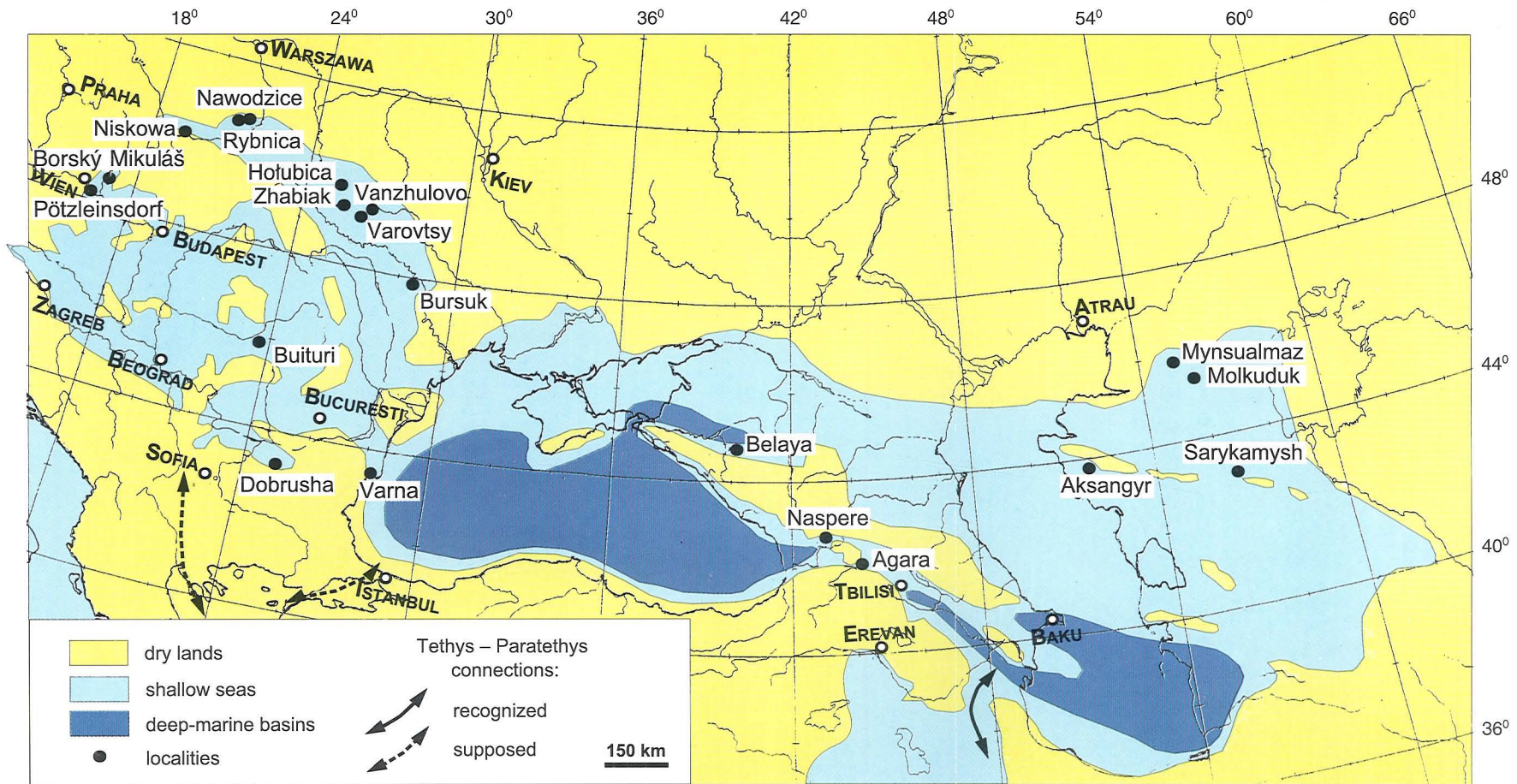
& STEININGER (1979, 1983, 1984) that in the Late Badenian, after the closure of the Transtethyan Trench “Corridor”, the Central Paratethys was linked with the Indo-Pacific part of the Tethys through the Eastern Paratethys (RÖGL & STEININGER 1983, Pl. 10). The Konkian bivalve fauna of the Eastern Paratethys is significantly less diversified than the Late Badenian fauna of the Central Paratethys (97 vs 316 species), and shows no Indo-Pacific affinity. The Konkian gastropods (ILJINA 1993), scaphopods (GONTSHAROVA 1975), and echinoids (NEVESSKAJA & *al.* 1986) are also less diversified. Moreover, KÓKAY (1985) has proved that the reason of the faunal impoverishment in the Konkian Sea, in comparison with the Late Badenian Sea, was in its lower salinity. Consequently, the connection between the Central Paratethys with the Indo-Pacific through the Eastern Paratethys, as proposed by STEININGER & *al.* (1978), was unacceptable for KÓKAY. In this case marine euhaline fauna migrating from the Indo-Pacific should have been able to traverse the Konkian Sea before settling down finally in the Late Badenian Sea. Unfortunately, KÓKAY (1985) proposed a still operative western connection as an explanation of the similarities between the Late Badenian and Mediterranean faunas, which is in strong contradiction with the geological data.

Eastern Paratethys

As mentioned above, in the late Chokrakian temporal closure of the Middle Araks Straight had taken place and semi-marine conditions prevailed in the Eastern Paratethys. The isolation of this area from the world ocean resulted in a drastic change of the bivalve fauna. Of 71 species known in the early Chokrakian only 6 are recorded in the late Chokrakian. The Karaganian fauna consists of 11 endemic species namely, *Lutetia* (*Davidaschvilia*) *intermedia*, *L. (Spaniodontella) gentilis*, *L. (S.) ersaconensis*, *Savanella andrussovi*, *Barnea kubanica*, *B. scrinia*, *B. sinzovi*, *B. ujraticumica*, *B. pseudoujraticumica*, *B. ustjurtensis*, and *B. pseudoustjurtensis*, but only two of them are survivors from the late Chokrakian, viz. *Lutetia* (*D.*) *intermedia* and *Barnea ujraticumica* (KOJUMDIEVA 1965, NEVESSKAJA & *al.* 1986, 1993, GONTSHAROVA 1989).

An exception to this was the middle Karaganian Varnean episode, when marine

Late Badenian – Konkian (age-equivalent of the early Serravallian) palaeogeography of the Central and Eastern Paratethys



The map simplified and compiled after HÁMOR (1988, Map 4), MOLYAVKO & KHAIN (1962, Map 78), GONTSHAROVA & SHCHERBA (1997, Fig. 3)

migrants appeared in the Eastern Paratethys for a short time. The most diversified Varnean assemblage found in north-western Usturt (Transcaspian area) contains *Aequipecten malvinae*, *Acanthocardia andrusovi*, *Cerastoderma praeplicata*, *Eastonia rugosa*, *Clausinella basteroti*, *Gafrarium eximium*, *Callista italica* and *Neovererella ustjurtensis*. All these species except the last re-populated the Eastern Paratethys in the Konkian.

At the beginning of the Konkian normal marine waters again invaded the Eastern Paratethys and a marine bivalve fauna again became established. Of 97 species recorded in Konkian strata, the only Karaganian survivors are four species of the genus *Barnea* RISSO, viz. *B. kubanica*, *B. pseudoustjurtensis*, *B. scrinia*, and *B. ujraticca*. No other Chokrakian genus survived the Karaganian salinity crisis in the Eastern Paratethys. Therefore, the Konkian fauna predominantly consists of species that had survived in areas adjacent to the Eastern Paratethys, and re-invaded it during the Konkian transgression.

The greatest diversity of Konkian gastropods (ILJINA 1993) and bivalves is observed in the Transcaspian area of the Eastern Paratethys (Table 1, columns 40-42) which is the only area where representatives of the following genera have been found: *Atrina* GRAY, *Linga* DE GREGARIO, *Megaxinus* BRUGNONE, *Anodontia* LINK, *Pterolucina* CHAVAN, *Cardites* LINK, *Lutraria* LAMARCK, *Arcopagia* BROWN, and *Gafrarium* RÖDING.

Moreover, on the basis of echinoids (NEVESSKAJA & al. 1986) and scaphopods (GONTSHAROVA 1975) found in the Transcaspian area, NEVESSKAJA & al. (1986, 1987) suggested that the Eastern Paratethys has been connected with the world ocean in its southern or south-eastern part. This connection, through eastern Turkey or Iran, was already earlier proposed by ZHIZHENKO (1940), and the precise location of this passage, between the Iranian Karadag and Talysh, was indicated by KHAIN (1964). The recent study by ILJINA (1995), GONTSHAROVA & SHCHERBA (1997) has confirmed that the passage, the Middle Araks Straight, was operative during Konkian time.

In the present authors' opinion, the Middle Araks Straight, re-opened in the early Konkian, is one of two connections linking the Eastern Paratethys with other marine basins. This is supported by the composition of the bivalve assemblages. Of 97 species constituting the Konkian bivalve fauna there are 7 endemics the occurrence of

which is restricted to the Eastern Paratethys, viz. 5 species of *Barnea* RISSO (of which only *B. bulgarica* appeared in the Konkian while remaining 4 species are relicts of the Karaganian), and 2 species of *Acanthocardia* GRAY, viz. *A. andrusovi* and *A. turkmenica*. Presumably *Acanthocardia* (A.) *paucicostata* is ancestral to *A. (A.) andrusovi*, reported from both Karaganian and Konkian strata, whereas the immediate ancestor of *Acanthocardia* (A.) *turkmenica*, reported from Transcaspian area and northern Iran (STUDENCKA & POPOV 1996), has not been identified.

As many as 70 species found in the Konkian of the Eastern Paratethys are geographically widespread (Table 1 columns 43, 44). Out of 97 species constituting the Konkian fauna, 20 species appear to be restricted to the Paratethyan Province. It is remarkable that 9 of them, originated in the Early Badenian, were definitely restricted to the Central Paratethys, but in the Late Badenian entered the Eastern Paratethys together with the following species: *Musculus sarmaticus*, *Palliolium bittneri*, *Ervilia podolica*, *E. trigonula*, *Donax (Paradonax) dentiger*, *Abra (Syndosmya) alba scythica*, *A. (S.) reflexa*, *Gomphomarcia secunda*, *Venerupis (Politiapes) modesta*, *V. (P.) vitaliana*, and *Timoclea (Parvivenus) konkensis*.

Apart from *Palliolium bittneri*, recorded from the Upper Badenian of Bulgaria (KOJUMD-GIEVA 1969), the Ukraine (KAZAKOVA 1952), Poland (KRACH 1979), and from the Konkian of the Precaucasus (KAZAKOVA 1952, NEVESSKAJA & al. 1993), and *Gomphomarcia secunda* recorded from the Upper Badenian of the West Ukraine (the MZ collection), and from the Konkian of both western Georgia and Transcaspian areas (Table 1, columns 36, 39, 41), the remaining 9 species which have their first appearance in the Upper Badenian – Konkian, are also reported from the Lower Sarmatian of both the Central and Eastern Paratethys (ILJINA & al. 1976, NEVESSKAJA & al. 1993).

The species restricted to the Paratethys Province constitute more than 20% of the Konkian fauna and provide, in the present authors' opinion, good evidence of faunal interchange between the Central and Eastern Paratethys. These bivalve data support foraminiferal evidence that during the Late Badenian – Konkian a broad connection between both parts of the Paratethys existed (DIDKOVSKY & NOSOVSKY 1975). The gastropod data indicating that

Konkian fauna changed longitudinally, from the most diversified eastern assemblages of the Transcaspien area to the most impoverished western localities of the Ukraine, were presumably the reason for doubts regarding the existence of this connection (NEVESSKAJA & *al.* 1984, 1986, 1987). However, such doubts were unnecessary because, in the area between the rivers Prut and Dniestr in the Moldova, the deposits proving this connection were found (ROSHKA & KHUBKA 1981). The most recent study by GONTSHAROVA & ILJINA (1997) also confirms the existence of the Predobrogean Strait between the Podolian Massif and the Meosian Platform.

In conclusion, the study of the bivalve fauna presented in this paper has demonstrated that in the Late Badenian – Konkian (age-equivalent of the early Serravallian) both parts of the Paratethys were linked together and connected independently in the south with the East Mediterranean province. Moreover, the present authors' study has proved that the original area for *Obsoletiforma obsoleta*, *O. kokkupica*, *Cerastoderma praeaplicata* and *Mactra (Sarmatimactra) eichwaldi*, which flourished in semi-marine Early Sarmatian Sea and gave origin to other species, was the Central Paratethys. The oldest finds of these species are in the Lower Badenian localities.

Origin of the Sarmatian fauna

The preceding discussion indicates that the Konkian fauna of the Eastern Paratethys developed by migration of species from both the East Mediterranean and Central Paratethys after the Karaganian crisis. It is notable that the species common to the Late Badenian fauna and its contemporaneous Konkian fauna (*see* ANDREEVA-GRIGOROVICH & NOSOVSKY 1976, MUZYLEV & GOLOVINA 1987, POPESCU 1987) constitute over 90% of the entire Eastern Paratethyan assemblage.

The later history of this uniform marine fauna has been strongly influenced by the closure of the Mediterranean seaways in both the Central and Eastern Paratethys, which took place in the latest Badenian – Konkian time. In both parts of the Paratethys, significant faunal impoverishment is documented (*cf.* LASKAREW 1903, GRISHKEVICH 1970, ILJINA & *al.* 1976, KÓKAY 1985). The bivalve fauna from both the uppermost Badenian (Buglovian s.s. of GRISHKEVICH 1970) and upper

Konkian (Veselianian) strata consist predominantly of species known to be only subordinate element 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 to Sarmatian species.

The endemic forms of the latest Badenian – Konkian reached its highest development in the Early Sarmatian. As a matter of fact, no similarity at all existed between the Mediterranean and Paratethyan faunas. However, the Sarmatian fauna, represented only by following euryhaline families Mytilidae, Cardiidae, Mactriidae, Mesodesmatidae, Semelidae, Donacidae and Veneridae, characterized by endemic forms, specific to particular basins has not been analysed in the present paper.

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