Diversity dynamics of Early–Middle Jurassic brachiopods of Caucasus, and the Pliensbachian–Toarcian mass extinction

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Taxonomic diversity of NW Caucasus brachiopods changed cyclically in the Early–Middle Jurassic. Diversifications took place in the Late Sinemurian–Early Pliensbachian, Middle–Late Toarcian and Late Aalenian–Early Bajocian, while diversity decreases occured in Late Pliensbachian–Early Toarcian, Early Aalenian and Late Bajocian. Outstanding diversity decline in the Late Pliensbachian–Early Toarcian corresponds to a global mass extinction interval, whose peak has been documented in the Early Toarcian. Similar diversity changes of brachiopods are observed in other Tethyan regions, including the well-studied Bakony Mountains, although in NW Caucasus the recovery after demise have begun earlier. The causes of Pl-To mass extinction in the studied region are enigmatic. Probably, it could be linked to anoxia, but its correspondence to the beginning of transgression is not coincident with the global record, so eustatic causes seem to be doubtful for this region.

Key words: Brachiopoda, taxonomic diversity, mass extinction, Jurassic, Caucasus, Russia.

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Introduction

The Late Pliensbachian–Early Toarcian (Early Jurassic) mass extinction is one of the most significant events in geological history. Although it is often called a "small" mass extinction in relation to such great biotic crises as Permian–Triassic or Cretaceous–Tertiary ones, it has been recognized for many principal groups of fossil organisms: foraminifers, bivalves, brachiopods and ammonoids (Hallam and Wignall 1997). Moreover, it provides an excellent example to study possible causal relations of mass extinctions to anoxia, major sea-level changes and intensive volcanism. The knowledge on the Early Jurassic mass extinction has grown thanks to the studies of Hallam (1961), who analyzed the fossil record, and Jenkyns (1988), who identified oceanic anoxia. In the past decade numerous publications on Liassic biotic changes by Hori (1993), Bassoullet and Baudin (1994), Little and Benton (1995), Aberhan and Fürsich (1997, 2000), Hallam and Wignall (1997, 1999), Harries and Little (1999), Guex et al. (2001), Wignall (2001), Jenkyns et al. (2002), and others have substantially added to previous results. A special study was dedicated to establishing the precise absolute radiometric age of the mass extinction, which is now accepted as 183±2 Ma (Pálfy et al. 2002).

Although one of the main fossil groups used to dicsuss the Late Pliensbachian–Early Toarcian (Pl-To) mass extinction are Bivalvia (Aberhan and Fürsich 1997, 2000; Harries and Little 1999), Brachiopoda seem to be no less important. Their significance in discussion of this decimation has been shown in articles of Hallam (1987), Bassoullet and Baudin (1994), and Vörös (1993, 1995, 2002).

Every mass extinction should be studied both using comparative global and regional data analyses to understand better its appearance in geological time and space. Results of quantitative analysis of taxonomic diversity dynamics of Early–Middle Jurassic brachiopods of Northwestern Caucasus are presented in this paper. The appearance of a biotic crisis in this Tethyan region allows one to extend the area where this mass extinction can be documented.

Geological setting

In the Mesozoic the Caucasus region was located on the northern active periphery of Tethys (Lordkipanidze et al. 1984; Meister and Stampfli 2000). Although brachiopods have been found in Jurassic deposits in this entire region, the most complete data are from NW Caucasus (Fig. 1). In tectonical aspect this territory covers 3 major tectonic zones: Labino-Malkinskaja zone, Pshekish-Tyrnyauzskaja zone and Arkhyz-Guzeripl'skaja zone (Rostovcev et al. 1992).

The Lias to Dogger stratigraphy and lithology of NW Caucasus have been described by Krymgolc (1972), Rostovcev et al. (1992), Granovskij et al. (2001), Ruban (2002), and also in *Stratigrafičeskij slovar'* (1979). The Rhaetian–Hettangian interval corresponds to a major regional hiatus. Smaller hiatuses divide Pliensbachian from Toarcian strata and Aalenian from Bajocian ones. Sinemurian–Pliensbachian deposits about 500 m thick include conglomerates, sandstones, dark shales and rare limestones. Lower–Middle (lower interval) Toarcian deposits (up to 70 m thick) are

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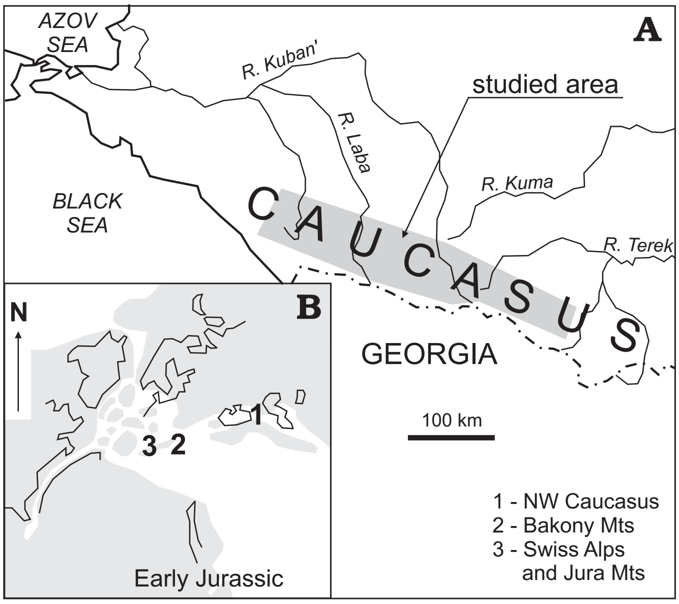

Fig. 1. Geographic location of studied area (**A**) and paleogeographic situation of areas discussed in the text (**B**; studied area indicated by 1). Paleogeographic base map is modified from Owen 1983 and Dommergues et al. 2001.

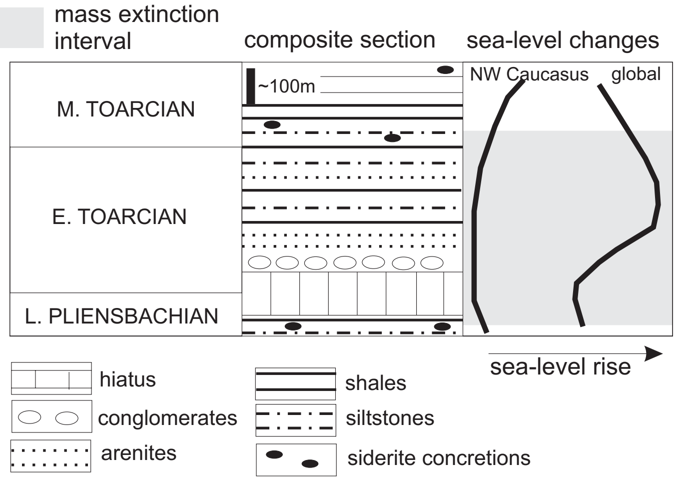

Fig. 2. Liassic composite lithological section of NW Caucasus and comparison of regional and global (simplified from Hallam and Wignall 1999) sea-level changes.

terrigenous (Fig. 2), but in the Middle (upper interval)–Upper Toarcian and Aalenian 1500 m of laminated dark to black shales have been accumulated. Bajocian deposits are represented by dark shales (up to 1200 m), often with interbeds of terrigenous or volcanogenous deposits. Dark shales contain siderite concretions. The highest concetration of them has been observed in the Middle–Upper (lower interval) Toarcian (Ruban 2002). But both rare dark shales horizons and concretions have been found also in the Middle (lower interval) Toarcian deposits.

The Jurassic paleoenvironments of the studied territory have been described in thanks of geochemical studies and numerous paleogeographical reconstructions by Âsamanov (1978). The Sinemurian sea was relatively shallow with normal salinity, the climate was subtropical and humid, and in the Pliensbachian the basin became deeper. Regression took place in Late Pliensbachian–Early Toarcian times followed by a fast transgression that started in the end of Middle Toarcian and in the Late Toarcian–Early Aalenian marine basin was deep. Dark shales of this interval are interpreted as slope deposits (Granovskij et al. 2001). The paleotemperatures of sea-water were about 20–22°C. Regression occured in the Aalenian, and the climate became more moderate. Paleotemperatures decreased to 10°C, while in the Late Aalenian they were once again about 20–23°C. In Bajocian the sea became deep and the climate returned to be subtropical and humid. Paleotemperatures identified were 25–27°C. In general terms, during all the Early–Middle Jurassic the Caucasus basin was not separated from the Tethyan ocean too much.

Materials

Early to Middle Jurassic brachiopods of NW Caucasus are rather well-studied. The first complete revisions have been made by Neumayr and Uhlig (1892), and then by Moiseev (1934) followed by the works by Makridin and Kamyšan (1964), Prosorovskaya (1986, 1989, 1993), and Rostovcev et al. (1992).

The most complete and taxonomically revised data on stratigraphic distribution of brachiopods have been presented by Makridin and Kamyšan (1964), Prosorovskaya (1989, 1993) and Rostovcev et al. (1992). These sources have been used to compile the diversity data, following by some revisions and stratigraphical corrections. In the whole 83 species from the Lower Jurassic and 51 ones from Middle Jurassic were recognized (see Appendix). The stratigraphical ranges of taxa are as detailed as the substages recognized in the ammonite succession (Rostovcev et al. 1992).

Total species quantity, and number of originations and extinctions have been calculated for each substage from Sinemurian to Bajocian to analyze the taxonomic diversity dynamics.

Species diversity dynamics

Species diversity of brachiopods changed dramatically in NW Caucasus (Fig. 3). After the great diversification in the Sinemurian–Early Pliensbachian (up to 54 taxa), a severe diversity decline occured in Late Pliensbachian. This trend continued into the Early Toarcian, when brachiopods disappeared entirely. In the Middle–Late Toarcian a new gradual diversification took place (total diversity reached 14 taxa), although it did not compensate for the previous decline. Once again brachiopods disappeared in the Early Aalenian (probably two taxa are

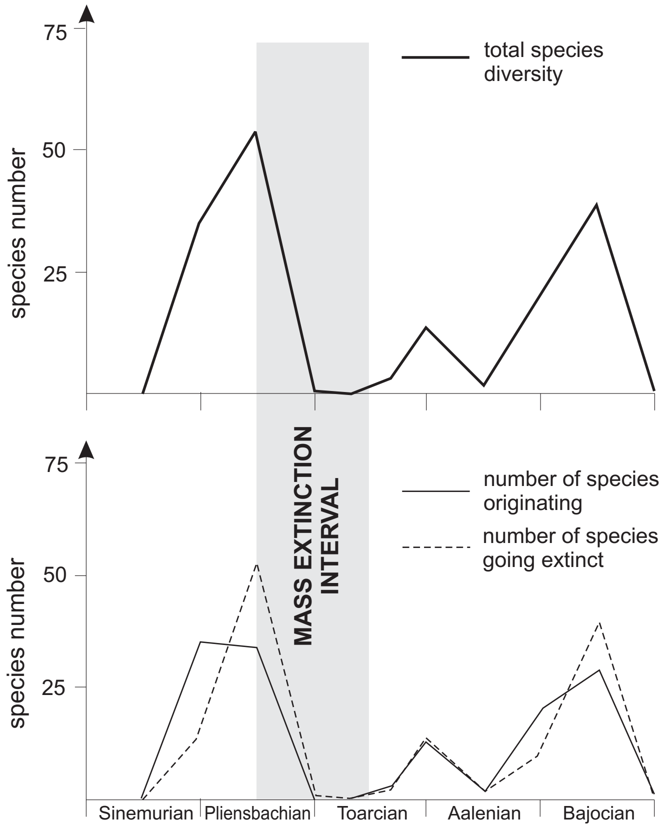

Fig. 3. Total species diversity changes, origination and extinction rates of NW Caucasus brachiopods in Early–Middle Jurassic.

known). Then a new acceleration of diversity is observed during Late Aalenian–Early Bajocian. Later Middle Jurassic brachiopod communities became extinct again. But the most outstanding features of the regional brachiopod history are the Late Sinemurian–Early Pliensbachian acme followed by Late Pliensbachian–Early Toarcian demise.

The origination and extinction rates help us to understand the causes of such turnovers (Fig. 3). Late Sinemurian–Early Pliensbachian diversification has been followed by increase both of origination and extinction. When the disappearance rate became higher, a regional diversity drop occured. Also the Late Pliensbachian–Early Toarcian demise of brachiopods corresponded to collapse of origination rate. The Early Aalenian and Late Bajocian crises also can be explained in the same way.

An analysis of events connected with disappearance of fossils should always take into account so-called Lazarus-taxa (Flessa and Jablonski 1983; Jablonski 1986; Wignall and Benton 1999; Fara 2001). The Lazarus effect causes a significant gap in any taxon's range. Among Early–Middle Jurassic brachiopods of the studied region only three Lazarus-taxa have been found (see Appendix). The interval of their absence covers the Late Pliensbachian–Early Toarcian in the NW Caucasus, and for two of them—also the Middle Toarcian. It is evident, that such a negligible Lazarus effect could not significantly influence the above mentioned results.

Discussion

Regional record of Pl-To crisis.—As shown above, the most intensive drop in brachiopods diversity occured in Late Pliensbachian–Early Toarcian. This time interval approximately corresponded to the mass extinction, whose most intensive phase embraced the Early Toarcian (Hallam and Wignall 1997). As the Caucasus sea was connected with Tethys, there was no barrier to isolate the local biota from the disastrous global factors.

The ecosystem collapse was indeed the most profound in the Early Toarcian, when brachiopods regionally disappeared. However, whilst the decrease of diversity began only in the Late Pliensbachian; the decline of origination rate was documented already in the Early Pliensbachian. In this timespan, the benthos disappearance also intensified, and the initial phase of the crisis took possibly place in the Early Pliensbachian. The recovery of brachiopods has been documented in the Middle Toarcian. But only the intensification of benthic colonization and total species diversity increased (i.e., the repopulation stage) in the Late Toarcian can be considered as a record of the final crisis termination. So, severe extinction have certainly influenced development of the Caucasus brachiopod biota during the Late Pliensbachian–Middle Toarcian.

It is improtant to compare the brachiopods diversity data with those of other shelly benthos like bivalves. The most recent compilative paper devoted to Jurassic pectinoids from the southern regions of the former Soviet Union, including Caucasus, has been published by Romanov and Kasum-Zade (1991). Stratigraphic ranges chart presented by these authors allows the recalculating of the total species quantity changes through the Late Liassic (Fig. 4). After a rather strong diversification of pectinoids in the Pliensbachian a relatively small diversity drop (~30%) is recognizable in the Early Toarcian. The species number was relatively low till the Bajocian when a new rise occured. This diversity changes means: (1) decline of bivalves was not as significant as that of the brachiopods, and (2) it occured after a great diversification event which is similar to those observed for brachiopods.

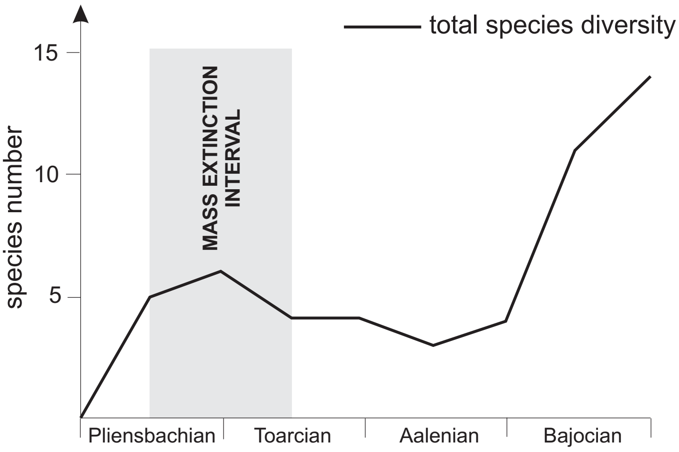

Fig. 4. Diversity changes of Spondylydae, Limidae, Plicatulidae, Anomiidae (Pectinoida) from the South of former Soviet Union (after Romanov and Kasum-Zade 1991).

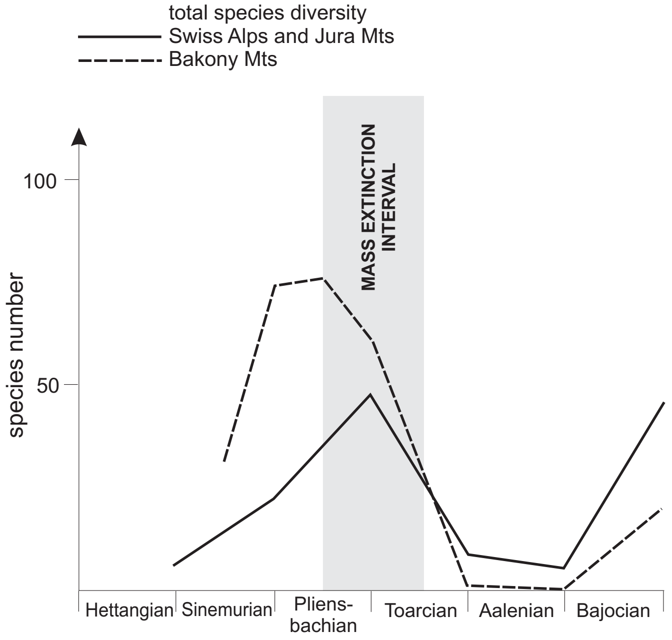

Fig. 5. Brachiopods diversity changes in Lias of Bakony Mts (after Vörös 1993, 1995) and Swiss Alps and Jura Mts. (after Sulser 1999).

Comparison with other regions.—Early Jurassic brachiopod diversity patterns was studied in other Tethyan regions, the best exemplified being in the Bakony Mountains in Hungary (Vörös 1993, 1995). The results show that total species number increased from the Hettangian to the Early Pliensbachian (Fig. 5). Then in the Late Pliensbachian a decrease began, while through the Toarcian–Aalenian interval brachiopods disappeared almost entirely. Origination rate began to decrease in the Carixian, and extinction rate increased the same time but more intensively in the Domerian. A new radiation has been documented in the Bajocian.

Diversity dynamics of Swiss Alps and Jura Mountains brachiopods could be calculated from data of Sulser (1999). Although in this monograph only partial stratigraphical ranges are shown (i.e., where taxa are abundant), the Sinemurian–Pliensbachian diversification phase, and Toarcian–Aalenian diversity fall are evident as well (Fig. 5).

Therefore, temporal diversity patterns of Tethyan brachiopods are very similar to those of NW Caucasus brachiopods although a recovery of diversity in the Late Toarcian shows a shorter crisis duration. But another feature is common for these regions: the mass extinction occurred after significant diversification, which seems to be connected with a radiation phase.

Causes of the shelly benthos collapse in NW Caucasus

The Early Jurassic mass extinction is thought to be causally connected mainly with anoxia and major sea-level changes (see reviews by Hallam and Wignall 1997, 1999; Wignall 2001). As the Pliensbachian–Toarcian boundary transition is marked in Caucasus by a hiatus, it is considered that at this time a local uplift took place; after the accumulation of Early Toarcian inner shelf sediments, the progressive deepening has begun in the Middle Toarcian (Granovskij et al. 2001).

The global sea-level curve (Haq et al. 1987; Hallam 1988, 2001; Hallam and Wignall 1999) shows eustatic rise that occurred distinctly earlier (in the Early Toarcian), and a regressive phase has already begun in the Middle Toarcian. A difference between the NW Caucasus and global sea-level record is evident (Fig. 2), while the results of diversity studies are similar. So, the Pl-To extinction among brachiopods in the studied region possibly should be explained by additional causes. It is necessary to note that previous attempts of explanations of Pl-To biotic crisis by sea-level fluctuations led to conclusion about the absence of direct links between these phenomena (McRoberts and Aberhan 1997).

Anoxic conditions are well established world-wide in Toarcian seas (Jenkyns et al. 2002). Although the broad shallowing trend has been observed, oxygen-depleted conditions can be tentatively inferred due to black colour of shales, common occurrence of siderite concretions and pyrite grains presence (Fig. 2). The dark colour may be interpreted as a result of the organic lamination. In the sections exposed along the Belaja River, the author has found interlayers fully consisted of siderite concretions in terrigenous deposits of the Lower–Middle (lower interval) Toarcian succession (Ruban 2002). Meantime, siderite is not considered as a direct indicator of anoxia.

It is necessary to point out that taking into consideration different regional factors may lead us to the correction of assumptions presented above; e.g., regional subsidence if it was intense could have disguised any local evidence of anoxia. The accounting of the same factor also may enforce us to reestimate the importance of transgressions–regressions. So, this a matter for further studies and discussions.

Nevertheless, the Caucasus record gives another opportunity to analyze the causes of possible anoxia themselves in the light of a recent scenario by Guex et al. (2001). The marine oxygen depletion is connected with the terrestrial plants diversification in the Early–Middle Liassic and linked with extensive land inundation during a transgressive pulse, when this accumulated organic material was able to initiate the anoxia. Macrofloral remains in the Domerian–Early Toarcian deposits are abundantly found in all studied sections (Ruban 2000), which might indicate a major plant diversification just before the beginning of Pl-To mass extinction. The same temporal link is observed in the global record (Philippe et al. 1999).

Conclusions

Three diversification episodes of brachiopod faunas, followed by diversity decline, have been documented in NW Caucasus marine basin, and the benthos diversity changed cyclically in the Early–Middle Jurassic. But the most dramatic change occurred in Late Sinemurian–Early Toarcian when diverse brachiopod communities experienced a severe extinction. Similar diversity patterns have been reported from coeval biota in other Tethyan regions (e.g., Vörös 1993, 1995). Such benthos collapse was obviously related to killing environmental factors operating globally through the Late Pliensbachian to the Early Toarcian (?anoxia), even if the direct causal mechanisms remain still enigmatic in the region studied. Expanding oxygen deficiency is a main candidate, and frequently discussed as a main environmental trigger of Palaeozoic brachiopod demises (e.g., Racki 1998; see also Hallam and Wignall 1997; Harper and Rong 2001; Rong and Shen 2002).

In comparison to the Bakony Mts, Jura Mts., and Swiss Alps, brachiopod recovery began earlier in this northern Tethyan domain. Therefore, the regional diversity pattern of the Early Jurassic biotic crisis could be traced even more clearly, and this is a promising perspective for elaboration of other fossil groups. The Caucasus sequences can serve a "reference" for further high resolution stratigraphical and ecological-geochemical studies of this biotic turning point in the Mesozoic.

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Appendix

List and stratigraphic ranges of Liassic Brachiopoda of Northwestern Caucasus (compiled from Makridin and Kamyshan 1964; Prosorovskaya 1989, 1993; Rostovtsev et al. 1992). S2, Sinemurian; P1, Early Pliensbachian; P2, Late Pliensbachian; T1, Early Toarcian; T2, Middle Toarcian; T3, Late Toarcian.

Species	S2	P1	P2	T1	T2	T3
“Rhynchonella” babala Dumortier						+
“Rhynchonella” latifrons Geyer		+				
“Rhynchonella” reinesi Gemmelaro	+					
“Rhynchonella” ex gr. *obtusiloba* Rollier					+	
“Spiriferina” moeschi Haas	+	+				
Aulacothyris griffini Rollier						+
Aulacothyris resupinata (Douville)		+				
Aulacothyris salgirensis Moissejev		+				
Aulacothyris waterhousi (Davidson)		+				
Bodrakella aff. *bodrakensis* Moissejev		+				
Calcirhynchia plicatissima (Quenstedt)	+	+				
Caucasorhynchia visnovskii Moissejev		+				
Cincta leptonumismalis (Rollier)		+				
Cincta cf. *numismalis* (Valenciennes)		+				
Cirpa borissiaki Moissejev		+				
Cuersithyris radstockensis (Davidson)		+				
Cuneirhynchia dalmasi (Dumortier)		+				
Cuneirhynchia gussmani (Rollier)		+				
Cuneirhynchia persinuata (Rau)		+				
Cuneirhynchia rauei Rollier		+				
Curtirhynchia sp.						+
Digonella subdigona (Oppel)		+				
?*Disculina liasina* Deslongchamps		+				
Flabellirhynchia lycetti (Davidson)		+				+
Furcirhynchia laevigata (Quenstedt)	+					
Gibbirhynchia curviceps (Quenstedt)		+				
Gibbirhynchia gibbosa Buckman	+	+				
Gibbirhynchia heiningensis Rollier						+
Grandirhynchia capitulata (Tate)						+
Homoeorhynchia deffneri Oppel	+	+				
Homoeorhynchia sp. 1		+				
Homoeorhynchia sp. 2						+
?*Linguithyris bimammata* Rothpletz	+					
Liospiriferina alpina (Oppel)		+				+
Liospiriferina obtusa (Oppel)	+	+				
Liospiriferina rostrata (Schlotheim)	+	+				
Liospiriferina cf. *obtusa* (Oppel)		+				
Lobothyris havesfieldensis Rollier						+
Lobothyris punctata (Sowerby)		+	+			
Lobothyris subpunctata (Davidson)		+				
?*Lobothyris ovatissima* Quenstedt		+				
Piarorhynchia juvenis (Quenstedt)	+					
Piarorhynchia rostellata (Quenstedt)		+			+	
Piarorhynchia triplicata (Phillips)		+				

Species	S2	P1	P2	T1	T2	T3
Piarorhynchia variabilis Davidson		+				
Piarorhynchia aff. *albertii* (Oppel)		+				
Praemonticlarella schuleri (Oppel)						+
Prionorhynchia greppini (Oppel)	+					
Prionorhynchia serrata (Sowerby)					+	+
?*Prionorhynchia regia* Rothpletz		+				
Pseudogibbirhynchia jurensis (Quenstedt)						+
Pseudogibbirhynchia moorei (Davidson)						+
Ptyctorhynchia sp.						+
Rimirhynchia rimosa (Buch)		+				
Rudirhynchia belemnitica (Quenstedt)	+					
Rudirhynchia calcicosta (Quenstedt)	+					
Scalpellirhynchia scalpellum (Quenstedt)	+					
Securina partschi (Oppel)	+	+				
Spiriferina haasi Makridin and Kamyshan	+					
Spiriferina haueri (Suess)	+	+				
Spiriferina ilminsteriensis Davidson	+					
Spiriferina walcotti (Sowerby)	+	+				
Spririferina angulata Oppel		+				
Squamirhynchia squamiplex (Quenstedt)		+				
Tetrarhynchia pontica Moissejev	+					
Zeilleria cornuta Quenstedt	+	+				
Zeilleria davidsoni Makridin et Kamyshan	+	+				
Zeilleria engelhardii (Oppel)		+				
Zeilleria indentata (Sowerby)	+	+				
Zeilleria lunaris (Zieten)		+				
Zeilleria mutabilis (Oppel)	+	+				
Zeilleria ovalis Rollier	+					
Zeilleria ovimontana (Boese)	+	+				
Zeilleria perforata (Piette)	+					
Zeilleria rehmanni (Roemer)	+	+				
Zeilleria retusa Martin	+	+				
Zeilleria roemeri (Schloenbach)	+					
Zeilleria scalprata (Quenstedt)	+	+				
Zeilleria stapia (Oppel)	+	+				
Zeilleria subsphaeroidalis Rollier	+					
Zeilleria thurvieseri Boese	+	+				
Zeilleria vicinalis (Schlotheim)	+	+				

ГЕОЛОШКИ АНАЛИ БАЛКАНСКОГА ПОЛУОСТРВА ANNALES GÉOLOGIQUES DE LA PÉNINSULE BALKANIQUE	66 (2004–2005)	9–15	БЕОГРАД, децембар 2005 BELGRADE, December 2005

The Upper Miocene of the Rostov Dome (Eastern Paratethys): Implication of the chronostratigraphy and bivalvia-based biostratigraphy

DMITRY A. RUBAN

Abstract. The Rostov Dome is located in the south of the Russian Platform. In the Late Miocene this area was embraced by the Eastern Paratethys. The implications of a recently developed Neogene chronostratigraphy to the studied area are discussed. The Sarmatian regional stage corresponds to the upper part of the Langhian, the entire Serravalian and the lower part of the Tortonian global stages; the Maeotian regional stage corresponds to the upper part of the Tortonian and the lowermost horizons of the Messinian global stages; the Pontian regional stage corresponds to most of the Messinian and the lowermost Zanclean global stages. A first Bivalvia-based biostratigraphic framework is proposed for the territory of the Rostov Dome. Five biozones were established within the Serravalian–Messinian: *Tapes vitalianus*, *Cerastoderma fittoni–Cerastoderma subfittoni*, *Congeria panticapaea*, *Congeria amygdaloides navicula* and *Monodacna pseudocatillus–Prosodacna schirvanica*.

Key words: regional stages, chronostratigraphy, biozones, bivalves, Upper Miocene, Eastern Paratethys.

Апстракт Ростовска дома налази се на југу руске платформе. За време касног миоцена ова област припадала је Источном Паратетису. Разматран је значај савремене неогене хроностратиграфије за проучавану област. Сарматском регионалном кату одговара део лангиана, цео серавалиан и доњи део тортона; меотском регионалном кату одговара горњии део тортона и најнижи хоризонти месиниана; понтском регионалном кату одговара већи део месиниана и најнижи занклеан. По први пут се даје биостратиграфија горњег миоцена на основу шкољака за област ростовске доме. У оквиру саравалиан–месиниан установљено је пет биозона: *Tapes vitalianus*, *Cerastoderma fittoni–Cerastoderma subfittoni*, *Congeria panticapaea*, *Congeria amygdaloides navicula* и *Monodacna pseudocatillus–Prosodacna schirvanica*.

Кључне речи: регионални катови, хроностратиграфија, биозоне, шкољке, горњи миоцен, источни Паратетис.

Introduction

The study of the Upper Miocene deposits of the Eastern Paratethys began about 150 years ago (ABICH, 1865; ANDRUSOV, 1884; ANDRUSSOW, 1911), but some important questions on their stratigraphy are still unresolved. Correlation between global and regional stages (1) and the development of macrofauna-based biozonation (2) are among them.

The Rostov Dome is a promising area to study the Upper Miocene stratigraphy of the Eastern Paratethys. It is situated in the southern part of the Russian Platform (Fig. 1). The Upper Miocene sedimentary complexes are wide-spread and cover all its territory. The high abundance of fossil bivalves in the Upper Miocene deposits of the Rostov Dome suggests the use of this group for the development of the first regional biostratigraphic framework. To do this, it was first necessary to implement the recently developed chronostratigraphy of the Upper Miocene in order replace the regional scale of the Eastern Paratethys.

Geological setting

The Rostov Dome is situated in the South of the European part of Russia (Fig. 1). In a tectonical sense, it represents a specific structure in the eastern part of the Precambrian Ukrainian Craton, which itself is a great block of the Russian platfrom (LEBEDKO, 1980;

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POGREBNOV *et al.*, 1970). After its uplift in the Cretaceous–Paleogene, the dome has several times been covered by the sea from the south.

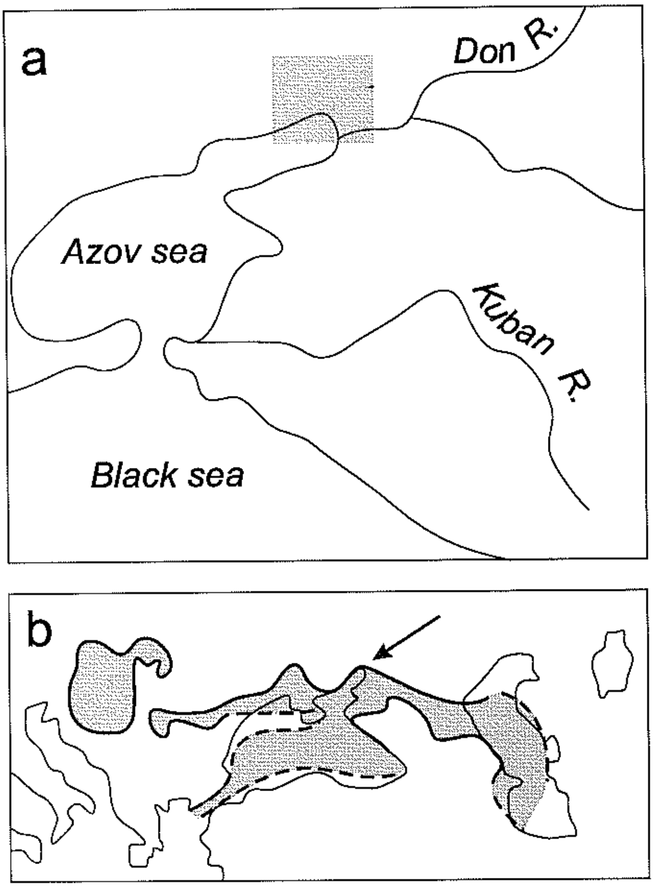

Fig. 1. Geographical (a) and palaeogeographical (b) locations of the studied area (shaded in a and indicated by an arrow in b). Palaeogeographical reconstruction after NEVESSKAJA *et al.* (1984).

In the Neogene, all the south of the European part of Russia was occupied by a large basin. It was a remnant of the previously existing Neotethys, which, after the orogeny in the alpine regions, became divided into 2 parts – the Mediterranean and the so-called Paratethys, consisting of Western (Pannonian), Central and Eastern Basins. The Paratethys originated at the end of the Paleogene, and its isolation strengthened cyclically from the Oligocene until the Pliocene (ILINA *et al.*, 1976; NEVESSKAJA *et al.*, 1984; NOSOVSKIJ, 2001; RÖGL, 1998, 1999; ULANOVSKAYA, 1998). The territory of the Rostov Dome is located at the northernmost periphery of the Eastern Paratethys (Fig. 1). It was embraced by sea during the maximums of cyclically repeating transgressions, when a relatively large and wide Tanaiss palaeobay originated (RUBAN, 2002a). Various sediments accumulated during these times – clays, silts, sands, marls, limes. But the most typical Upper Miocene deposits are skeletal limestones, consisting completely of shells of bivalves, less gastropods and their remains of different size.

Although the Upper Miocene deposits are well-exposed in outcrops within the studied area, they have been investigated only occasionally during the XX century by BOGATCHOV (see RODZJANKO, 1970) and later by RODZJANKO (1970, 1986). Also they have been characterized in few monographs, e.g., PAFFENGOLTS (1959), IVANITSKAJA & POGREBNOV (1962), but these descriptions mostly summarized the results of the above mentioned researchers.

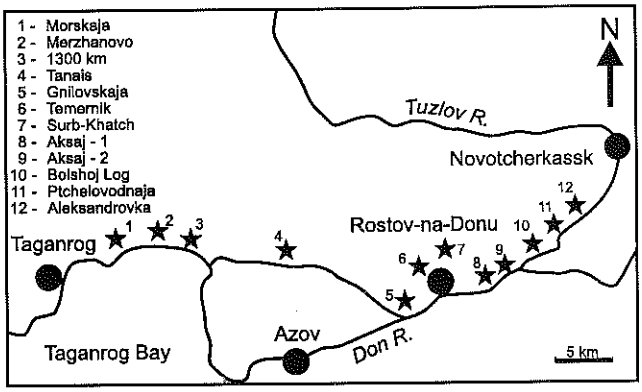

Fig. 2. Location of the studied sections of the Upper Miocene deposits of the Rostov Dome.

The author studied 12 sections of the Upper Miocene strata of the Rostov Dome (Fig. 2) and made a lithostratigraphic framework (Figs. 3, 4). Taganrogskaja, Rostovskaja, Donskaja, Merzhanovskaja and Aleksandrovskaja Formations were formally defined (RUBAN, 2002b). The Janovskaja Formation was established previously by RODZJANKO (1986). Additionally, RUBAN & YANG (2004) proposed a first sequence stratigraphic framework for the Upper Miocene deposits of the Rostov Dome.

Bivalves from the Upper Miocene deposits were studied (RUBAN, 2002b). Identification of the species was made according to general overviews (with taxonomic descriptions and figures) of Neogene bivalves of the Eastern Paratethys presented by ILINA *et al.* (1976) and NEVESSKAJA (1986).

Implication of the chronostratigraphic scale to the Eastern Paratethys

Normalization of the general stratigraphic framework of the Eastern Paratethys, i.e. to correlate global and regional stages, is an important task, because this will enable correlations of biostratigraphic units, which may be defined in the Upper Miocene of the Rostov Dome, to be made to adjacent and even far-located regions.

When in the XIX century differences between the Mediterranean and the Paratethys were established, the general problem of Neogene strata correlation between

Fig. 3. Generalized lithostratigraphy of the Upper Miocene deposits of the Rostov Dome.

these territories appeared. Differences in the stratigraphy between the Western and the Eastern Paratethys arose. In the 1980s and 90s, the Mediterranean stratigraphic scale of the Neogene coupled with world-wide data underwent revision by the International Comission on Stratigraphy (ICS) in order to develop a globally-significant chronostratigraphic scale. This procedure is ongoing, and a new precise chronostratigraphic scale is "under construction". When the development of the recent chronostratigraphic scale began, the difficulties in making a correlation between the global and the regional Eastern Paratethys stratigraphies strengthed again.

The "International stratigraphic Guide" (Salvador, 1994) proclaims stages as units with a global sense. Thus, it cannot be defined essentially for a particular region, because the geologic time was not different in the palaeospace. Meanwhile, when stratigraphers begin to define further global units, there is often insuficient data to enable the consideration of globally-recognized horizons in the studied interval. In this way, separate standards of stages appear. Each of them is valid for a single region. The stages in such standards are regional stages.

Nowadays, there are at least two intervals for which regional stages are widely used: Cambrian (Palmer, 1998; Zhuravlev, 1995) and Carboniferous (Menning *et al.*, 2000, 2001; Wagner & Winkler Prins, 1983). Discussions about which regional stages are preferable are ongoing. However, every time, when evidence is obtained which enables larger global units to be defined (as in the case of the Upper Miocene), it is not necessary to use regional stages. It is clear that different chronostratigraphies for particular regions should no

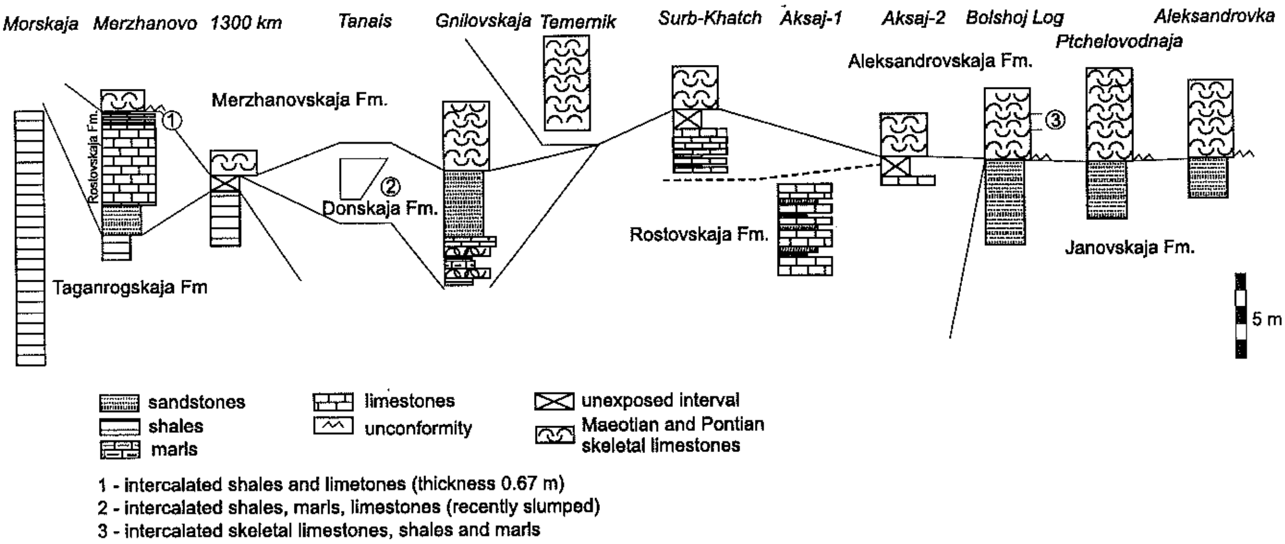

Fig. 4. Correlation of the sections of the Upper Miocene deposits of the Rostov Dome.

longer exist, because the geological time was the same at every point on the Earth's surface. Otherwise, chaotic nomenclature, not representing the true geologic history will result.

In the meantime, Russian stratigraphers traditionally continue to use the regional stratigraphic scale for the Neogene deposits, which includes regional stages differing from chronostratigraphic (i.e., global) stages (Fig. 5). A widely accepted version of such a regional scale was proposed by NEVESSKAJA *et al.* (1984, 1986) and NEVESSKAJA (1986) . Therefore, there is an urgent need to correlate global and regional stages and to implicate the chronostratigraphy to the Eastern Paratethys in order replace the regional standard and abandon it forever.

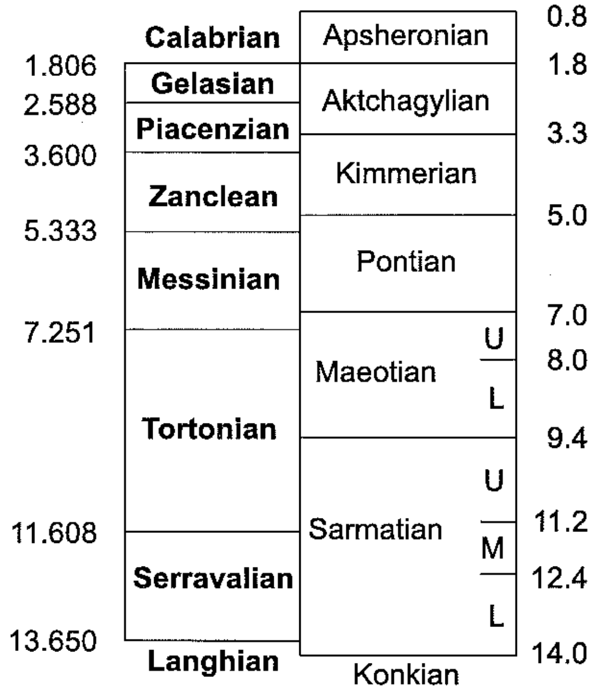

Fig. 5. Correlation between the chronostratigraphic units of the Upper Miocene–Pliocene and the regional stages of the Eastern Paratethys (see text for sources of the absolute ages).

A possible way to correlate the Neogene chronostratigraphic and regional stages is to compare the absolute ages of their boundaries. For the Eastern Parathethys these ages were evaluated precisely by TCHUMAKOV *et al.* (1992), and then discussed several times (TCHUMAKOV, 2000a, b). For the recently employed chronostratigraphic units, the absolute ages are recommended by the ICS (GRADSTEIN *et al.*, 2004) and some of them have been defined in the Global Stratotype Sections and Points (GSSPs) (CASTRADORI *et al.*, 1998; HILGEN *et al.*, 1998, 2000a, b; RIO *et al.*, 1998; VAN COUVERING *et al.*, 2000). For the formal definition of absolute ages of the Messinian, all the Pliocene stages were preferred. ICS recommendations (GRADSTEIN *et al.*, 2004) were used for the Laghian, Serravalian and Tortonian stages.

The results of a correlation by absolute ages (Fig. 5) suggest the Sarmatian regional stage corresponds to the upper part of the Langhian, the entire Serravalian, and the lower part of the Tortonian global stages. The Maeotian regional stage embraces the upper part of the Tortonian and the lowermost horizons of the Messinian global stages. And finally the Pontian regional stage mostly corresponds to the Messinian with only the uppermost part corresponding to the lowermost Zanclean. It is evident, that Miocene/Pliocene boundary, located at the base of the Zanclean in the global scale, has a different position in the Eastern Paratethys, where check meaning the Zanclean is established at the base of the Kimmerian.

Bivalvia-based biostratigraphy of the Rostov Dome

Abundant bivalves remains are the characteristic feature for all the Upper Miocene strata of the Rostov Dome. The analysis of taxa ranges allows the development of the regional biozonation based on this fossil group. Previous studies of the Eastern Paratethys (ILINA *et al.*, 1976; NEVESSKAJA, 1986; NEVESSKAJA *et al.*, 1986) resulted only from malacofaunal support for the regional stages and their substages and from the occasional identification of specific units, called "beds with", which, in fact, are something like acme-zones or assemblage zones. The present study of the Rostov Dome, however, permits the development of a Bivalvia-based biostratigraphy.

The definition of the biostratigraphic units (biozones) was made according to the recommendations of the ICS (SALVADOR, 1994). The difference of terms "first occurence level" (FOL) and "last occurence level" (LOL) from "first appearance datum" (FAD) and "last appearance datum" (LAD) is assumed as the one proposed by PAVIA & MARTIRE (1997). Five distinct biozones have been defined in the Upper Miocene strata of the Rostov Dome (Fig. 6). The correlation established between regional and chronostratigraphic stages helped in the asignment of these biozones to global stages.

***Tapes vitalianus* Interval Zone** corresponds to the interval from the pre-Upper Miocene malacofauna assemblage (not represented in the studied sections) to the LOL of *Tapes vitalianus* ORBIGNY. Further studies are necessary to revise this zone, as its lower boundary is undefined. Age: Langhian–Serravalian; Lower Sarmatian. Reference sections: Morskaja, Merzhanovo.

***Cerastoderma fittoni* – *Cerastoderma subfittoni* Total Ranges Zone** corresponds to the interval from the FOLs of *Cerastoderma fittoni* (ORBIGNY) and *C. subfittoni* (ANDRUSOV) to the LOLs of these taxa. Age: Serravalian–Tortonian; Middle Sarmatian. Reference section: Merzhanovo.

***Congeria panticapaea* Interval Zone** corresponds to the interval from the FOL of *Congeria panticapaea*

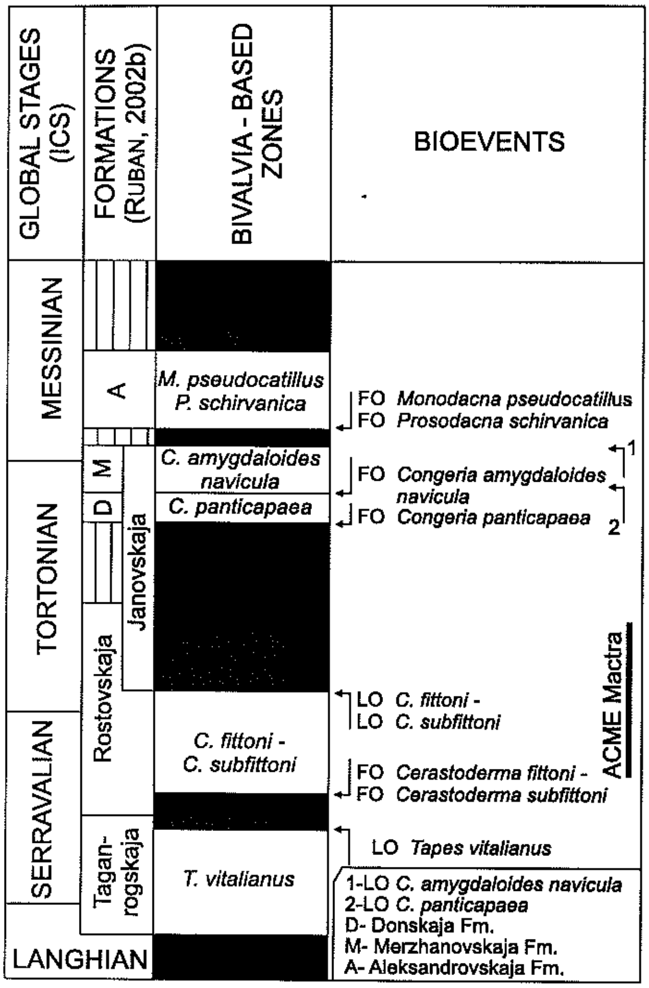

Fig. 6. Proposed Bivalvia-based biostratigraphy of the Upper Miocene of the Rostov Dome.

ANDRUSOV to the FOL of *C. amygdaloides navicula* ANDRUSOV. It is important to note that the LOL of *C. panticapaea* ANDRUSOV is above the upper boundary of this zone. Age: Tortonian; "beds with *C. panticapaea*", lower part of the Upper Maeotian. Reference section: Gnilovskaja.

Congeria amygdaloides navicula **Total Range Zone** corresponds to the interval from the FOL to the LOL of *Congeria amygdaloides navicula* ANDRUSOV. Age: Tortonian–Lowermost Messinian; "beds with *C. amygdaloides navicula*", upper part of the Upper Maeotian. Reference sections: Merzhanovo, 1300 km.

Monodacna pseudocatillus* – *Prosodacna schirvanica **Interval Zone** corresponds to the interval from the FOLs of *Monodacna pseudocatillus* BARBOT and *Prosodacna schirvanica* ANDRUSOV to the upper disconformal boundary of the Upper Miocene sedimentary complex. Age: Messinian; Lower Pontian. Reference sections: Bolshoj Log, Ptchelovodnaja, Aleksandrovka.

Unzoned intervals include hiatuses (at the base of the Donskaja and Aleksndrovskaja Formations) and short intervals where zonality could not be established because of the scarcity of fossils remains (the transition between Taganrogskaja and Rostovskaja Formations, upper part of Rostovskaja Formation, and Janovskaja Formation).

All the above mentioned zones were defined by characteristic taxa bioevents. The last ones are very easy to be determined in the stratigraphic record. All these events seem to be isochronous at least within the area of the Rostov Dome.

Conclusions

The comparison of absolute ages permits a correlation of the global and regional stages for the Eastern Paratethys to be made.

Studies of the Upper Miocene deposits of the Rostov Dome resulted in the definifion of five distinct Bivalvia-based biozones. The implicated chronostratigraphy coupled with the Bivalvia-based biozonation seems to be a real alternative for replacing the previously developed regional stratigraphy, based on the definition of regional stages.

Further research should be aimed at extending the defined biozones to the entire territory embraced by the Eastern Paratethys.

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Appendix

In addition to the formal definition of the Merzhanovskaja Formation (RUBAN, 2002b), a detailed indication of particular beds of skeletal limestones in the Merzhanovo stratotype section is presented below (see this section location and whole composition in Fig. 2, 4). The Beds are numbered from base to top.

LOWER MEMBER (beds 1–10) – 1.26 m
bed 1 – 0.05 m
bed 2 – 0.15 m
bed 3 – 0.04 m
bed 4 – 0.08 m
bed 5 – 0.02 m
bed 6 – 0.11 m
bed 7 – 0.08 m
bed 8 – 0.18 m
bed 9 – 0.40 m
bed 10 – 0.15 m

UPPER MEMBER (beds 11–16) – 0.32 m
bed 11 – 0.03 m
bed 12 – 0.03 m
bed 13 – 0.04 m
bed 14 – 0.06 m
bed 15 – 0.06 m
bed 16 – 0.10 m
Total thickness 1.58 m.

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Резиме

Горњи миоцен Ростовске доме (Источни Паратетис): значај за хроностратиграфију и биостратиграфија на основу шкољака

Ростовска дома налази се на југу руске платформе. За време касног миоцена ова област припадала је Танајском палеозаливу Источног Паратетиса. И ако се миоценски седименти ове области проучавају око 100 година њихова детаљна стратиграфска подела још није приказана. На основу проучавања 12 изданака горњомиоценских успостављена је литостратиграфска (укупно 6 формација) и секвентна стратиграфија.

Регионални катови се углавном употребљавају и имају предност у Источном Паратетису. Њихова корелација са хроностратиграфским катовима предложених од стране Интернационалне комисије за стратиграфију је неопходна, зато што ће то омогућити корелацију стратиграфских јединица, као што се то може дефинисати за касни миоцен ростовске доме, са суседним или чак удаљеним областима. Када су катови, који су глобално препознатљиви, предложени, изгледа да није потребно да се употребљавају регионалнои катови, који су прихватљиви само у оним случајевима када се расправља о хроностратиграфској подели.

Покушана је примена недавно установљене неогене хроностратиграфије на област Ростовске доме. Ово је остварено кроз упоређење апсолутних старости граница две поменуте врсте катова. Сарматском регионалном кату одговара горњи део лангиана, целом серавалиану и доњем делу тортона. Меотском регионалном кату одговара горњи део тортона и најнижи хоризонти месиниана. Понтском регионалном кату одговара већи део месиниана и најнижи занклеан. Установљено је да граница миоцен/плиоцен, која се налази у бази занклеана, има различит положај у Источном Тетису, где је успостављена у бази кимерианског регионалног ката.

У горњомиоценских седимената ростовске доме нађени су многобројни остаци шкољака. Анализа распрострањења таксона дозволила је по први пут успостављење биостратиграфије на основу шкољака за територију Ростовске доме. У оквиру интервала серавалиан-месиниан установљено је пет биозона: *Tapes vitalianus*, *Cerastoderma fittoni–Cerastoderma subfittoni*, *Congeria panticapaea*, *Congeria amygdaloides navicula* и *Monodacna pseudocatillus–Prosodacna schirvanica*. Интервали без зона укључују хијатусе (у бази Донске и Александровске формације) и краћих интервала где зоналност није могла бити успостављена због ретких фосила (прелаз између Таганрогске и Ростовске формације, горњи део ростовске формације и јановске формације).

Наредна проучавања би требала бити усмерена на дефинисању биозона целе територије која је припадала Источном Паратетису.