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Cretaceous palaeogeography of the North-Eastern Peri-Tethys

Evgenij Yu. Baraboshkin *, Alexander S. Alekseev, Ludmila F. Kopaevich

Geological Faculty, Moscow State University, Vorobjovy Gory, 119899 Moscow, Russia

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Abstract

The Cretaceous stratigraphy and main palaeogeographic features of the North-Eastern Peri-Tethys are briefly summarised on the base of new data. The study is mainly focused on the time-slices that were chosen for the recently published Peri-Tethys Atlas: Early Hauterivian, Early Aptian, Late Cenomanian, Early Campanian and Late Maastrichtian. Two main epochs in the development of this area are recognised. The Early Cretaceous is characterised by the prevalence of the terrigenous sedimentation and the existence of a large longitudinal strait through the Russian Platform, which controlled the Boreal/Tethyan connection. The southward Boreal water movement prevailed during the Neocomian. The strongest Boreal transgression took place in the Late Hauterivian, when cool water reached the Crimea basin. The Aptian–Albian time was characterised by a northward Tethyan water movement, interrupted by the Early Albian Boreal transgression. Tectonic rebuilding of the region took place in the Albian–Cenomanian. It resulted in the disappearance of the sea-strait through the Russian Platform and in the opening of another sea-strait in the Turgai area in the Turonian. This strait connected the Peri-Tethyan seas, the Western Siberia Boreal basin and joined with the Western Interior Seaway in the other side of the Hemisphere. The Northern Hemisphere Megastrait appeared. During this time mainly carbonate sedimentation prevailed, but the existence of a new longitudinal strait determined a two-way water and faunal exchange. Tethyan water moved up to the south and the south-east parts of the Western Siberian basin, while the cold Boreal water influence can be recognised along the northern margin of the Russian Platform basin.

Keywords: Cretaceous; zonation; palaeogeography; North-Eastern Peri-Tethys

1. Introduction

The present paper summarises our knowledge on the palaeogeographic development of the area of the North-Eastern Peri-Tethys during the Cretaceous period. Although we try to briefly characterise the major palaeogeographical changes in this area for the whole Cretaceous, we do it in more detail for the time-slices that were chosen for the Peri-Tethys Atlas (Dercourt et al., 2000): Early Hauterivian, Early Aptian, Late Cenomanian, Early Campanian and Late Maastrichtian.

* Corresponding author. Fax: +7-95-932-88-89.
E-mail address: barabosh@geol.msu.ru
(E.Yu. Baraboshkin).

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The north-eastern sector of Peri-Tethys includes the following geological structures: East-European (Russian) Platform (RP), Scythian Platform (Plain Crimea and Pre-Caucasus area), Mountain Crimea, North Caucasus, Turanian Platform and Mangyshlak. One of the main palaeogeographical features of this region was controlling of the Tethyan/Boreal sea connection through a strait system. Two general epochs in the development of this area were recognised. The Early Cretaceous was characterised by the prevalence of the terrigenous sedimentation and Boreal/Tethyan connection through the Russian meridional strait, placed in the eastern part of the RP. During the Late Cretaceous mainly carbonate sedimentation prevailed and the Boreal basin connected with the Tethys through the Turgai strait of the Turanian Platform and also partially through a system of small Uralian straits. The time of rebuilding of tectonic structures of the whole area was in the Albian.

The present study is based on investigations of many geologists, but in most cases we will use our own investigations in stratigraphy and palaeogeography of this extended region as the base for the idea of the development of the region.

2. The Early Cretaceous

The Early Cretaceous palaeogeography of the North-Eastern Peri-Tethys region has been studied in numerous regional works. We used Burlin (1961) and Drushchits and Mikhailova (1966) for the North Caucasus, Nalivkin et al. (1964) and Sazonova and Sazonov (1967) for the RP, Tashliev and Tovbina (1992) for Tuarkyr–Kopet-Dagh area, Bulynnikova et al. (1978) and Korobeinikov et al. (1995) for Western Siberia and some others. Since the publication of most of these papers, the stratigraphical scales and consequently the correlation and palaeogeographical interpretation of the development of this area were strongly revised. Recently some of the features of palaeogeographical and palaeobiogeographical development of the region were discussed by Baraboshkin (1996, 1997c, 1999a, 2001, 2002) and Baraboshkin with co-authors (Baraboshkin et al., 1998; Baraboshkin, Olferiev in Dercourt et al., 2000).

2.1. Biostratigraphic schemes

The studied area crosses both Boreal and Tethyan palaeogeographical realms and one of the most difficult problems is the correlation of Boreal and Tethyan zonal scales. There were several times of appearance and disappearance of Boreal/Tethyan connection during the Early Cretaceous due to the opening/closing of the sea-straits in the Peri-Caspian, Pechora, Ural regions and in the west of the RP (Table 1). This means that we cannot make a direct zonal correlation for the Early Berriasian, Late Valanginian(?)–Early Hauterivian, Barremian and Late Aptian time, but for the other time-slices we can. In case of indirect correlation magnetostratigraphic and climatostratigraphic, palynostratigraphic and biogeographic methods were used. We can agree, however, that the correlation shown on Table 1 for the mentioned intervals is possible but needs further investigation.

Another problem is the high variability of palaeogeographic conditions in this area (from deep pelagic to continental) and high dynamics of palaeogeographic and climatic changes. Therefore we can not use only biostratigraphic groups even for zonal scales. Nevertheless, this scheme is based mainly on ammonites, the traditional group for the Lower Cretaceous, and on belemnites that were exceptionally used for the Hauterivian–Barremian zonation of the RP. As in recent cephalopods (Nesis, 1985), the most important factors, which limited their distribution (and therefore biostratigraphic zones) are: (1) temperature, (2) basin bathymetry, (3) mode of life, (4) trophic resources (Lehmann, 1981; Westermann, 1990). The post mortem transportation of ammonite shells, which is very important for correlation, seems not to play a significant role in their distribution. Other groups of marine fauna (forams, radiolarians, nannofossils) also had strong facial control and their zonation is not as detailed as for cephalopods.

As can be seen from the zonal scheme (Table 1), only the ammonite zonation for the Crimea is similar to the 'standard' zonation of the West Mediterranean Province (Hoedemaeker and Rawson, 2000), but even that has been affected by the Boreal water mass in the Late Hauterivian (Baraboshkin, 1997a,b).

There are several specific features in this zonal correlational scheme, which make it different from the previous schemes and some of these features are still under discussion.

(1) We accept the correlation of the Upper Volgian and the Lower Berriasian, following Casey et al. (1977), Hoedemaeker (1987), Sei and Kalacheva (1997), but use a different zonation for the RP (Baraboshkin, 1999a). We also accept the idea of Sakharov (1984) that it is reasonable to subdivide the Berriasian into two substages (Baraboshkin, 1999a). A Berriasian zonation drawn in Table 1 for the Crimea, Caucasus and Mangyshlak area has been modified after Luppov et al. (1988), Bogdanova et al. (1984, 1999), Kvantaliani (1989), Sei and Kalacheva (1997), and our own data (Baraboshkin, 1999a, 2001, 2002; Kopaevich et al., 1999; Yanin and Baraboshkin, 2000).

(2) The Valanginian zonation is slightly modified for the Crimea and Peri-Caspian–Mangyshlak after Baraboshkin (1999a), Baraboshkin and Mikhailova (2000), Baraboshkin and Yanin (1997), Kopaevich et al. (1999) and Luppov et al. (1983).

(3) The Hauterivian zonation for the Crimea is modified after Baraboshkin (1997b), for the Caucasus after Khryashchevskaya et al. (2000) and for the RP after Baraboshkin (2001, 2002) and Baraboshkin et al. (2001) and revised on the base of recent data.

(4) The Barremian zonation is modified after Baraboshkin (1997a) for the Crimea; for the North Caucasus it is new and based on data from a detailed study of Urukh section (North Osetia). For the RP it is recently supplemented by new data on the belemnite succession of Middle Povolzhie (Baraboshkin et al., 2001; Baraboshkin, 2001). There are two main differences between the belemnite zonation proposed for the RP and that for North Europe (Mutterlose, 1983; Rawson and Mutterlose, 1983): (a) the base of the Boreal Barremian is drawn by the first appearance of *Praeoxyteuthis*, which is confirmed by magnetostratigraphic data (in preparation), and (b) the generic name '*Aulacoteuthis*' we use in quotes, as it was recently determined by us that the true *Aulacoteuthis*, including the type species *Aulacoteuthis absolutiformis* (Sinzow), occurred near the base of the Upper Hauterivian *Speetoniceras versicolor* Zone. This fact, naturally, requires the revision of the genus and probably a change of the nomenclature for *Aulacoteuthis*.

(5) The Aptian zonation for Mountain Crimea was compiled after Yanin and Vishnevsky (1989) and Drushchits et al. (1981); the zonal scale of Drushchits and Mikhailova (1966) for the North Caucasus was completed by our own data from the Central part of the North Caucasus. The Aptian zonation for Mangyshlak (Kopaevich et al., 1999) is confirmed by the detailed data of Bogdanova (1999) for the lower substage. The zonation for the RP is based on Baraboshkin (1998) and Baraboshkin et al. (1999), but was seriously revised recently in its Lower Aptian part (Mikhailova and Baraboshkin, 2001; Baraboshkin, 2001).

(6) The Albian zonation for the studied area was discussed in Baraboshkin (1996, 1999b). The only significant difference from the 'standard zonation' is that we accept the base of the Middle Albian as it was originally determined by Casey (1954, 1961) and supported in early papers of Owen (1971), Mikhailova and Saveliev (1989) and Saveliev (1992) by the first appearance of ammonite genus *Isohoplites* (Baraboshkin, 1999b).

2.2. Composition of sections and major palaeogeographic changes

The Early Berriasian (= Late Volgian) was characterised by separation of the Boreal basin and the Tethys. The arid climate led to carbonate sedimentation in the Crimea–North Caucasus–Kopet-Dagh area and the formation of an evaporate belt to the north (Moskvin, 1986–1987; Bennenson, 1985; Tashliev and Tovbina, 1992). The other belt of red-coloured continental rocks along the Dnepr-Donets depression (Bilyk et al., 1960) and the dryland to the south-east (Buzachi

Table 1
Biostratigraphic schemes of the Lower Cretaceous of the Russian Platform, North Caucasus, the Crimea and correlation with the 'standard' zonation (Hoedemaker and Rawson, 2000); boreal zonal indexes are shaded

STAGE	SUBSTAGE	ZONAL STANDARD OF WESTERN MEDITERRANEAN, P.J.HOEDEMAEKER, P.F.RAWSON, 2000 — ZONE, SUBZONE	MOUNTAIN CRIMEA — ZONE, SUBZONE, BEDS WITH FAUNA	NORTH CAUCASUS — ZONE, SUBZONE, BEDS WITH FAUNA	PERICASPIAN AND MANGYSHLAK — ZONE, SUBZONE	RUSSIAN PLATFORM — ZONE, SUBZONE
ALBIAN	UPPER	Stoliczkaia dispar / Stoliczkaia dispar	Mortoniceras perinflatum	Mortoniceras perinflatum	Lepthoplites cantabrigensis / Pleurohoplites studeri	NON-MARINE?
		Stoliczkaia dispar / Stoliczkaia blancheti	Mortoniceras rostratum	Mortoniceras rostratum	Lepthoplites cantabrigensis / Callihoplit. vraconensis	Callihoplites vraconensis
		Morton. inflatum	Mortoniceras inflatum	Mortoniceras inflatum	Mortoniceras inflatum	Mortoniceras inflatum
			Hysteroceras varicosum	Hysteroceras varicosum	Semenovites michalskii	?
			Hysteroceras orbignyi	Hysteroceras orbignyi	Semenovites pseudocoelonodus	
		Morton. inflatum / Dipoloceras cristatum	?	Dipoloceras cristatum	Semenovites tamalakensis	Dimorphoplites beresovkaensis
	MIDDLE	Euhoplites lautus	Anahoplites daviesi	Euhoplites lautus	Anahoplites rossicus	Dimorphoplites rossiensis
		Euhoplites loricatus		?	Anahoplites daviesi	Hoplites dentatiformis
			MISSING	Daghestanites daghestanensis	Daghestanites daghestanensis	Dimorphoplites pretethydis
				Anahoplites intermedius	Anahoplites intermedius	
				Oxytropidoceras roissyanum	Hoplites spathi	Hoplites volguschensis
		Hoplites dentatus / Hoplites spathi		Hoplites spathi		Hoplites spathi
		Hoplites dentatus / Lyelliceras lyelli		Hoplites benettianus	Hoplites benettianus	Hoplites benettianus
		Douvilleiceras mammillatum		Isohoplites eodentatus	Isohoplites eodentatus	Isohoplites eodentatus
	LOWER			Douvilleiceras mammillatum / ?	Douvilleiceras mammillatum / Otohoplites crassus	Otohoplites auritiformis
				Douvilleiceras mammillatum / Tetrahoplites suborientalis	Douvilleiceras mammillatum / Tetrahoplites suborientalis	?
				Douvilleiceras mammillatum / Cleoniceras floridum	Douvilleiceras mammillatum / Sonneratia caperata	Cleoniceras floridum
					Douvilleiceras mammillatum / Sonneratia rotula	
				Douvilleiceras mammillatum / ?	Douvilleiceras mammillatum / Sonneratia subdragunovi	
					Douvilleiceras mammillatum / Sonneratia solida	
					Douvilleiceras mammillatum / Sonneratia perinflata	?
		Leymeriella tardefurcata		Leymeriella regularis	Sonneratia regularis	Anadesmoceras strangulatum
					Anadesmoceras strangulatum	
			? Leymeriella tardefurcata	Leymeriella tardefurcata	Leymeriella acuticostata	Arcthoplites belli
					Arcthoplites probus	
					Arcthoplites jachromensis	Arcthoplites jachromensis
					Leymeriella recticostata	Freboldiceras singulare
APTIAN	UPPER	Hypacanthoplites jacobi	MISSING	Hypacanthoplites jacobi	MISSING	CONTINENTAL TO NEAR-SHORE
		Nolaniceras nolani	? Nolaniceras nolani	Nolaniceras nolani	Nolaniceras nolani	
		Nolaniceras nolani / D. nodosocostatum				
	MIDDLE	Parahoplites melchioris	? / ?	Acanthohoplites uhligi	?	
			? / Acanth. aschiltaensis	Parahopl. melchioris / Acanth. aschiltaensis	Parahoplites melchioris	? Parahoplites melchioris
			? / Parahopl. multicostatus	Parahopl. melchioris / Parahopl. multicostatus		
		Epicheloniceras subnodosocostatum	A. nisus / Colomb. crassicostatum	Epicheloniceras subnodosocostatum	Epicheloniceras subnodosocostatum	Aconeceras nisus
	LOWER	Dufrenoya furcata	Aconeceras nisoides / ?	Dufrenoya furcata	Dufrenoya furcata	Tropaeum bowerbanki
		Deshayesites deshayesi	Aconeceras nisoides / Deshayesites deshayesi	Deshayesites deshayesi	Deshayesites deshayesi	Deshayesites deshayesi / Audouliceras renauxianum
						Deshayesites deshayesi / Proaustraliceras tuberculatum
		Deshayesites weissi	Aconeceras nisoides / ?	Deshayesites volgensis	Deshayesites weissi	Deshayesites volgensis / Ancyloceras matheronianum
						Deshayesites volgensis / Volgoceratoides schilovkensis
		Deshayesites tuarkyricus		Paradeshayesites weissi	CONTINENTAL TO NEAR-SHORE	Deshayesites tenuicostatus
BARREMIAN	UPPER	Pseudocrioceras waagenoides	Patruliusiceras uhligi	Matheronites ridzewskyi		Oxyteuthis lahuseni
		Colchidites sarasini		Colchidites securiformis		
		Imerites giraudi		Imerites giraudi		
		Hemihoplites feraudianus		Hemihoplites feraudianus		Oxyteuthis sp.
		Gerhardtia sartousiana / Gerhard. provincialis	Gerhardtia provincialis	Gerhardtia sartousiana / ?		Oxyteuthis brunsvicensis
		Gerhardtia sartousiana / Gerhard. sartousiana				
		Ancyloceras vandenheckii				

Table 1 (*Continued*).

BARREM.	LOWER	Moutoniceras moutonianum		Holcodiscus caillaudianus		H. caillaudianus	M. moutonianum	CONTINENTAL		"Aulacoteuthis" speetonensis	
		Kotetishvilia compressissima				?				Praeoxyteuthis pugio	
		Nicklesia nicklesi		Nicklesia pulchella						Praeoxyteuthis jasicofiana	
		Avramidiscus hugii		Taveraediscus hugii						Praeoxyteuthis hibolitiformis	
HAUTERIVIAN	UPPER	Pseudoth. angulicostata auctorum	Pseudothurmannia catulloi	Pseudothurmannia catulloi		Craspedodiscus discofalcatus				Hibolites jaculoides	
										Craspedodiscus discofalcatus	Crasped. discofalcatus
			Pseudothurmannia angulicostata auct.	Pseudothurmannia ohmi							Simbirskites umbonatus
											Simbirskites pseudobarboti
		Balearites balearis		Milanowskia speetonensis		Milanowskia speetonensis				Milanowskia speetonensis	
		Plesiospitidiscus ligatus		Speetoniceras inversum		Speetoniceras inversum				Speetoniceras versicolor	Speetoniceras pavlovae
											Speetoniceras inversum
											Simbirskites coronatiformis
		Subsaynella sayni		Crioceratites duvali							Speetoniceras versicolor
	LOWER	Lyticoceras nodosoplicatum		Lyticoceras nodosoplicatum		Crioceratites nolani				Pavlovites polyptychoides	
		Crioceratites loryi	Olcosteph. jeannoti	? Crioceratites loryi							
			Crioceratites loryi					?			
		Acanthodiscus radiatus		Leopoldia desmoceroides		Acanthodiscus radiatus				Homolsomites ivanovi	
VALANGINIAN	UPPER	Teschenites callidiscus		Eleniceras tauricum		?		Dichotomites bidichotomus		Dichotomites bidichotomus	
				Teschenites callidiscus							
		Himantoceras trinodosum	Criosaras. furcillata	Himantoceras trinodosum							
			Olcosteph. nicklesi								
		Saynoceras verrucosum	Vahr. peregrinus	Neohoploceras submartini	? V. peregrinus	Saynoceras verrucosum					
			K. pronecostatum		?						
			Sayn. verrucosum								
	LOWER	Busnardoites campylotoxus		Campylotoxia campylotoxa		Campylotoxia campylotoxa		Polyptychites polyptychus		Polyptychites polyptychus	
								? Polyptychites michalskii		Polyptychites michalskii	
		Thurmanniceras pertransiens		Thurmanniceras pertransiens		Beds with Requienia baksanensis		Nikitinoceras syzranicum		Nikitinoceras syzranicum	
		Thurmanniceras otopeta		Kilianella otopeta		Thurmanniceras thurmanni		MISSING		Pseudogarnieria undulatoplicatilis	
BERRIASIAN	UPPER	Fauriella boissieri	Tirnovella apillensis	Beds with Megadiceras koinautense		Beds with Advenina ullucolensis				Peregrinoceras albidum	
				Beds with Zeillerina baksanensis	Beds with Weberithyris moisseevi	Berriasella callisto				Surites tzikwinianus	
				Beds with Symphythyris arguinensis							
			Berriasella picteti	Tauricoc. crassicostatum		Riasanites rjasanensis	Tauriceras angulicostatum	Riasanites rjasanensis	Transcaspiites transfigurabilis	Riasanites rjasanensis	Transcaspiites transfigurabilis
			Malbosiceras paramimmounum	Euthymiceras euthymi			Euthymiceras euthymi		Euthymiceras euthymi		Hectoroceras kochi
									Transcaspiites transcaspius		Riasanites subrjasanensis
							Riasanites subrjasanensis	MISSING OR CONTINENTAL			
	LOWER	Tirnovella occitanica	Dalmasiceras dalmasi	Dalmasiceras tauricum		Dalmasiceras crassicostatum				Craspedites nodiger	Craspedites milkovensis
			Berriasella privasensis	Tirnovella occitanica		Tirnovella occitanica					Craspedites mosquensis
			Tirnovella subalpina			Malbosiceras malbosiforme				Craspedites subditus	
		Berriasella jacobi		Pseudosubplanites ponticus		Pseudosubplanites ponticus				Kachpurites fulgens	Craspedites nekrassovi
											Kachpurites fulgens

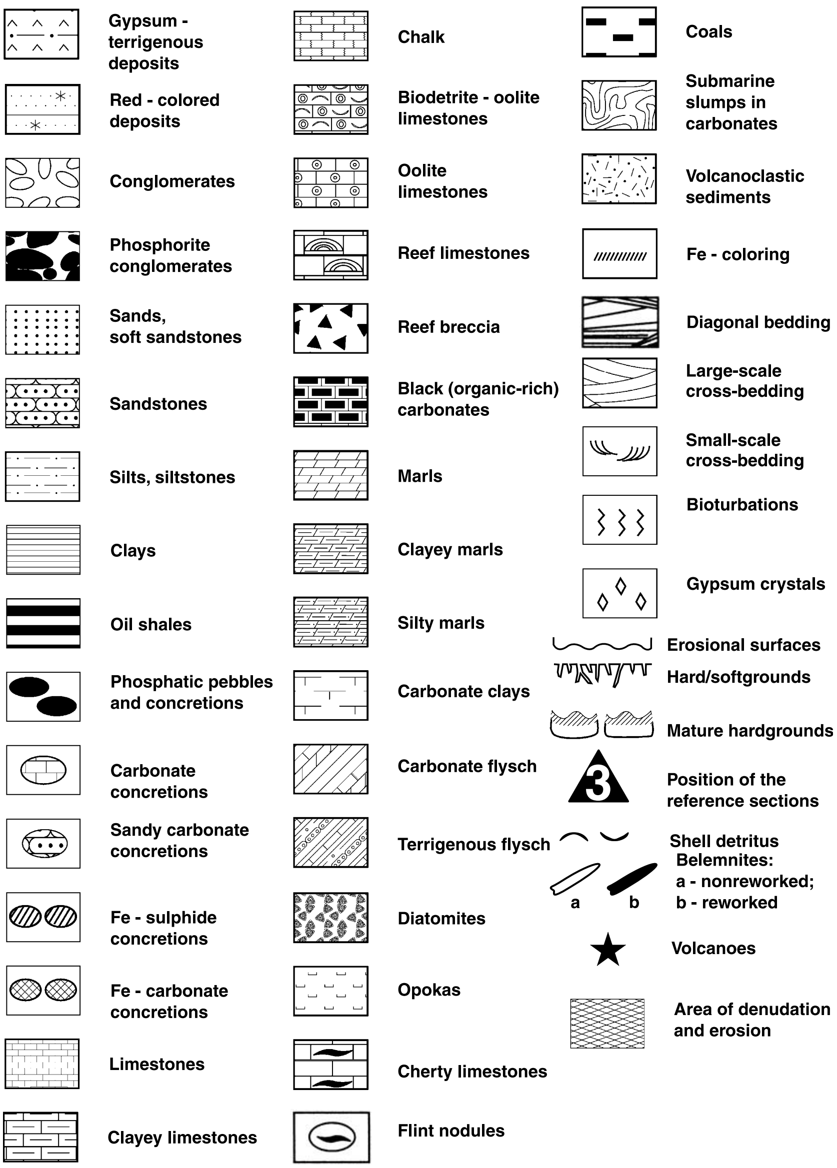


Fig. 1. Legend to Figs. 2–12.

Peninsula, Mangyshlak–Tuarkyr area) closed the North Caspian sea-strait. The RP basin was filled by phosphorite-bearing highly condensed terrigenous sediments (Gerasimov, 1969), which replaced a clay-marly succession in the south margin of RP basin (Sazonova and Sazonov, 1967). The RP basin had free connection with the Boreal Realm during the Early Berriasian through Mezen and Pechora basins (Sazonova and Sazonov, 1967; Saks et al., 1972) and probably shallow water straits connected RP and West Siberian basins (Baraboshkin, 1999a).

The Early/Late Berriasian transition is marked by a short-term phase of deformations in the Crimea–North-West Caucasus region (Mileev et al., 1997) and opening of the North Caspian strait (Baraboshkin, 1999a). This time is characterised by the penetration of Boreal fauna (*Hec-*

EARLY HAUTERIVIAN

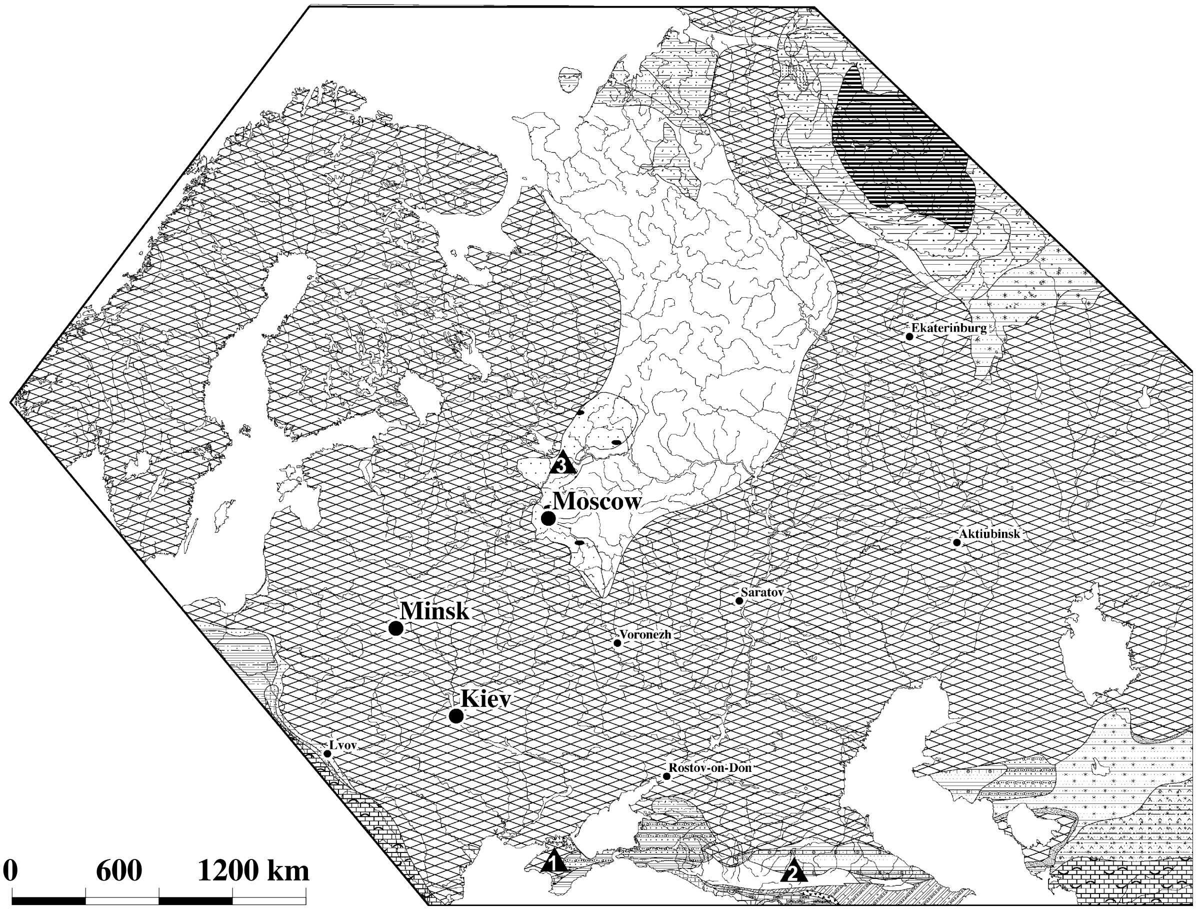
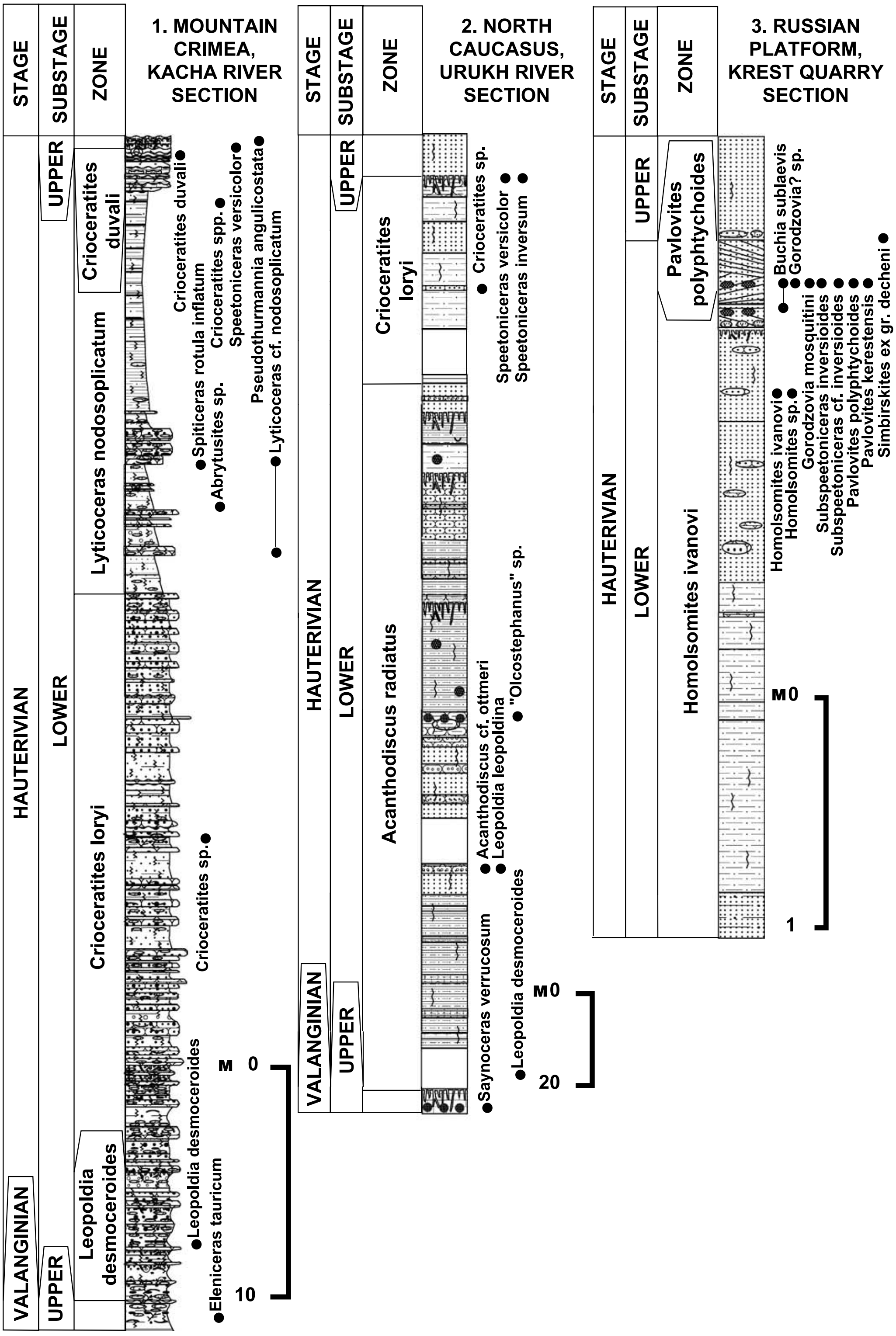


Fig. 2. Early Hauterivian palaeogeography of the North-Eastern Peri-Tethys. The legend is in Fig. 1.

toroceras, *Surites*: Mesezhnikov, 1984; Luppov et al., 1988) far to the south and Tethyan fauna far to the north (*Transcaspiites*, *Riasanites*: Dubeikovsky, 1969; Mesezhnikov, 1984). Additional shallow sea connections opened between Peri-Caspian and Turkmenian seas. This sedimentation continued after the Early Berriasian, but the evaporite and continental red-coloured belts disappeared.

During the Early Valanginian terrigenous marine to near-shore sediments cover the Mountain Crimea (Baraboshkin and Yanin, 1997), but in the North Caucasus–Kopet-Dagh area the carbonate sedimentation still was preserved (Drushchits and Mikhailova, 1966; Moskvin, 1986–1987). At the same time continental red- or varigated-coloured sediments of the Aral region start to expand westwards (Tashliev and Tovbina, 1992). The RP basin becomes shallower with very strong condensation of terrigenous sediments: the development of 'phosphorite plates' is usual even for relatively deeper parts of the basin (Middle Povolzhie). The Tethyan/Boreal connection was very restricted in the Peri-Caspian: if rare Boreal *Nikitinoceras* are known from Mangyshlak (Luppov et al., 1983), late Early Valanginian *Polyptychites*, as well as Late Valanginian *Dichotomites*, usually mentioned in faunal lists (Egoyan and Tkachuk, 1965; Drushchits and Mikhailova, 1966, etc.) were not figured



1. MOUNTAIN CRIMEA, KACHA RIVER SECTION
2. NORTH CAUCASUS, URUKH RIVER SECTION
3. RUSSIAN PLATFORM, KREST QUARRY SECTION
STAGE
SUBSTAGE
ZONE
HAUTERIVIAN
VALANGINIAN
UPPER
LOWER
Crioceratites duvali
Lyticoceras nodosoplicatum
Crioceratites loryi
Leopoldia desmoceroides
Acanthodiscus radiatus
Pavlovites polyphtychoides
Homolsomites ivanovi
Crioceratites duvali
Spiticeras rotula inflatum
Crioceratites spp.
Speetoniceras versicolor
Pseudothurmannia angulicostata
Lyticoceras cf. nodosoplicatum
Abrytusites sp.
Crioceratites sp.
Leopoldia desmoceroides
Eleniceras tauricum
Speetoniceras inversum
Acanthodiscus cf. ottmeri
Leopoldia leopoldina
"Olcostephanus" sp.
Saynoceras verrucosum
Buchia sublaevis
Gorodzovia? sp.
Simbirskites ex gr. decheni
Gorodzovia mosquitini
Subspeetoniceras inversioides
Subspeetoniceras cf. inversioides
Pavlovites polyphtychoides
Pavlovites kerestensis
Homolsomites ivanovi
Homolsomites sp.
м 0
10
м0
20
м0
1

anywhere, nor are they present in collections (Baraboshkin, 1999a). On the other hand, the only finding of *Neohoploceras* was documented from Mangyshlak (Gordeev, 1971). It confirms the possible presence of narrow marine connection between two basins.

The palaeogeography of the Late Valanginian is very similar to that of the Early Valanginian, but the RP basin became shallower and restricted in the Peri-Caspian and results in complete isolation from Tethys (Baraboshkin, 1999a).

The Early Hauterivian (Fig. 2, for legend see Fig. 1). is one of the time-slices, which were chosen for the Peri-Tethys Atlas (Baraboshkin in Dercourt et al., 2000). For the North-Eastern Peri-Tethys this interval is characterised by different development tendencies. In the Crimea it is the time of developed transgression, which covered the whole Mountain Crimea (Baraboshkin, 1997a,b). The terrigenous marine to near-shore sandy facies was present in central Crimea and in the Kacha River reference section in particular (Fig. 3). They were divided from the Simferopol uplift to the north by a narrow belt of condensed coral reef buildups. The area of the first Crimea range was submerged and clay sedimentation took place there. The age of the succession is confirmed by the presence of ammonite genera *Leopoldia*, *Breistrofferella*, *Lyticoceras* and some of *Crioceratites* (Fig. 3).

In the North Caucasus the Early Hauterivian transgression is shown by a break in sedimentation (carbonate to terrigenous) and a regional unconformity (Drushchits and Mikhailova, 1966; Bennenson, 1985; Moskvin, 1986–1987). It seems that the reference section proposed in the Baksan River (Egoyan and Tkachuk, 1965) is not complete enough (Khryashchevskaya et al., 2000), so recently we prepared data on the other possible reference section, the Urukh section (Figs. 2 and 3) in North Osetia. The Lower Hauterivian of this region is represented by a shallow marine sandy–clayey succession intercalated with limestone beds, which contains mainly Temperate and Tethyan marine fauna, including ammonites: *Acanthodiscus*, *Leopoldia* and *Crioceratites* of *nolani* group. The Mangyshlak and Turanian Platform were covered by the red-coloured continental Kugusem Formation with near-shore terrigenous sediments at the base (Luppov et al., 1983; Moskvin, 1986–1987). The deposits of this formation become more marine southward up to Kopet-Dagh with limestone formations (Fig. 2). The age of those limestones is not well documented and findings of '*Endemoceras*' and '*Distoloceras*' originally referred to the Lower Hauterivian in the Great Balkhan sections (Luppov and Prosorovsky, 1983) are more likely Upper Valanginian (?Lower Hauterivian) *Eleniceras* (Baraboshkin, 2001, 2002).

The area of the RP basin was strongly reduced because of an uplift. This event is marked by an important regression of the sea in RP and does not correspond with data for West Europe (Rawson, 1994, 1999). Shallow water sea conditions were defined only for the northern part of the RP and in particular for the reference section at the Krest Quarry, Yaroslavl region (Figs. 2 and 3), where endemic ammonites *Pavlovites*, *Subspeetoniceras* and *Gorodzovia* (Aristov, 1967; Shulgina et al., 1979) were found above *Homolsomites*. This fauna was found in a shallow marine sandy succession, which contains bivalves, brachiopods and abundant spores and pollen assemblages. Although the position of this specific fauna is under discussion (Golbert et al., 1977; Baraboshkin, 2001, 2002), its Early Hauterivian age was accepted (Jeletzky and Kemper, 1988; Shulgina, 1996).

Unlike the Early Hauterivian, the Late Hauterivian was the period of the strongest Boreal transgression (Baraboshkin, 2001, 2002), which covered almost the complete studied area. The transgression penetrated into Plain Crimea (Le-

Fig. 3. Lower Hauterivian reference sections of the Crimea (1, Kacha River section, after Baraboshkin, 1997b), North Caucasus (2, Urukh River section, E.Yu. Baraboshkin data) and the Russian Platform (3, Krest Quarry section, after Shulgina et al., 1979) and the key fauna distribution. The positions of the sections are marked with triangles in Fig. 2. The legend is in Fig. 1.

schukh, 1987), where terrigenous sedimentation started. In Mountain Crimea highly condensed 'Ammonitico Rosso' facies were formed and in the outer part of the basin clayey sedimentation took place (Baraboshkin, 1997b). In the North Caucasus–Kopet-Dagh region the Upper Hauterivian transgressively overlays the Lower Hauterivian and has a mixed terrigenous–carbonate composition. The area of the red-coloured continental deposits expanded westward and covered the whole Turanian Platform and North-Eastern Peri-Caspian. In the latest Hauterivian this strip of continental deposition crossed the North Peri-Caspian and separated Boreal basin and the Tethys again. It is probable that in the Late Hauterivian sea-straits connected the wide RP basin of muddy sedimentation with the West Siberian basin.

The Barremian palaeogeography is characterised by isolation of the RP basin from Tethys and different tendencies in basin development. In Plain Crimea terrigenous Barremian sediments transgressively overlay Hauterivian and older deposits (Leschukh, 1987). In Mountain Crimea they partially represented the upper part of 'Ammonitico Rosso' limestones and partially the lower part of the deep-water clayey sections (Yanin and Vishnevsky, 1989; Baraboshkin, 1997a,b,c). In the North Caucasus the Barremian succession is similar to the Hauterivian one (Burlin, 1961; Drushchits and Mikhailova, 1966; Khryashchevskaya et al., 2000). It starts by a transgression and finishes with a regressive sandy facies. In the Kopet-Dagh–Balkhan area the Barremian is represented mainly by marly limestone sections, replaced in the upper part by sandy sections to the north (Tashliev and Tovbina, 1992). The RP basin was separated from the North Caucasus–Kopet-Dagh basin in the south by an extended belt of red-coloured continental deposits. According to poor faunal assemblages (ammonites are virtually missing) and palynological data there was an influx of fresh water (Baraboshkin et al., 2001). This is supported by the presence of deltaic and avandeltaic facies in the SW of the RP basin. The sea connection with the West Siberia basin closed because of an uplift of the Ural Mountains and did not reopen before the Turonian.

The earliest Early Aptian (Fig. 4) palaeogeography was similar to the Barremian, but in marine successions of North Caucasus–Kopet-Dagh area the transition is usually marked by a stratigraphic gap. In Mountain Crimea the pelagic clays were deposited (Fig. 5). Ammonites are very rare with a few findings of *Deshayesites* and *Cheloniceras* (Fig. 5). The age of the clays is mainly determined by the foraminiferal data (Gorbachik, 1986; Yanin and Vishnevsky, 1989). The Kacha River reference section is very typical for Mountain Crimea. Other types of rocks are also present (Drushchits et al., 1981), but their position is still undetermined. The Lower Aptian of the North Caucasus is represented by clays with intercalations of siltstones and sandstones and contains numerous gaps, placed mainly at the base and at the top of the succession. The reference section (Fig. 5) is at Kislovodsk City (Drushchits and Mikhailova, 1966). It contains almost all of the Lower Aptian ammonite zones, confirmed by findings of indices of *Paradeshayesites weissi* (Neumayr et Uhlig), *Deshayesites volgensis* (Sasonova), *Deshayesites deshayesi* (Leymerie). The *Dufrenoya furcata* Zone is not well documented there, so additional reference sections should be chosen. A sandy marine member in the middle part of the Kislovodsk section is replaced by an avandeltaic cross-bedded member to the south-east and indicates an important sea-level drop.

Well-studied Lower Aptian sandy sections are situated in Turkmenistan and were proposed as reference sections for the Barremian/Aptian transition (Bogdanova and Prozorovsky, 1999). Many of the sections there, however, contain disconformities, represented by erosional surfaces and phosphorite pebbles. They are concentrated in the base and in the top of the Lower Aptian as is the case in North Caucasus sections. The ammonite documentation, however, is probably the best there (Bogdanova and Prozorovsky, 1999).

Mangyshlak Lower Aptian sections are represented by highly condensed shallow water conglomerates and phosphorite conglomerates, sandstones and siltstones. Before, in the Hauterivian–Barremian continental conditions existed in the

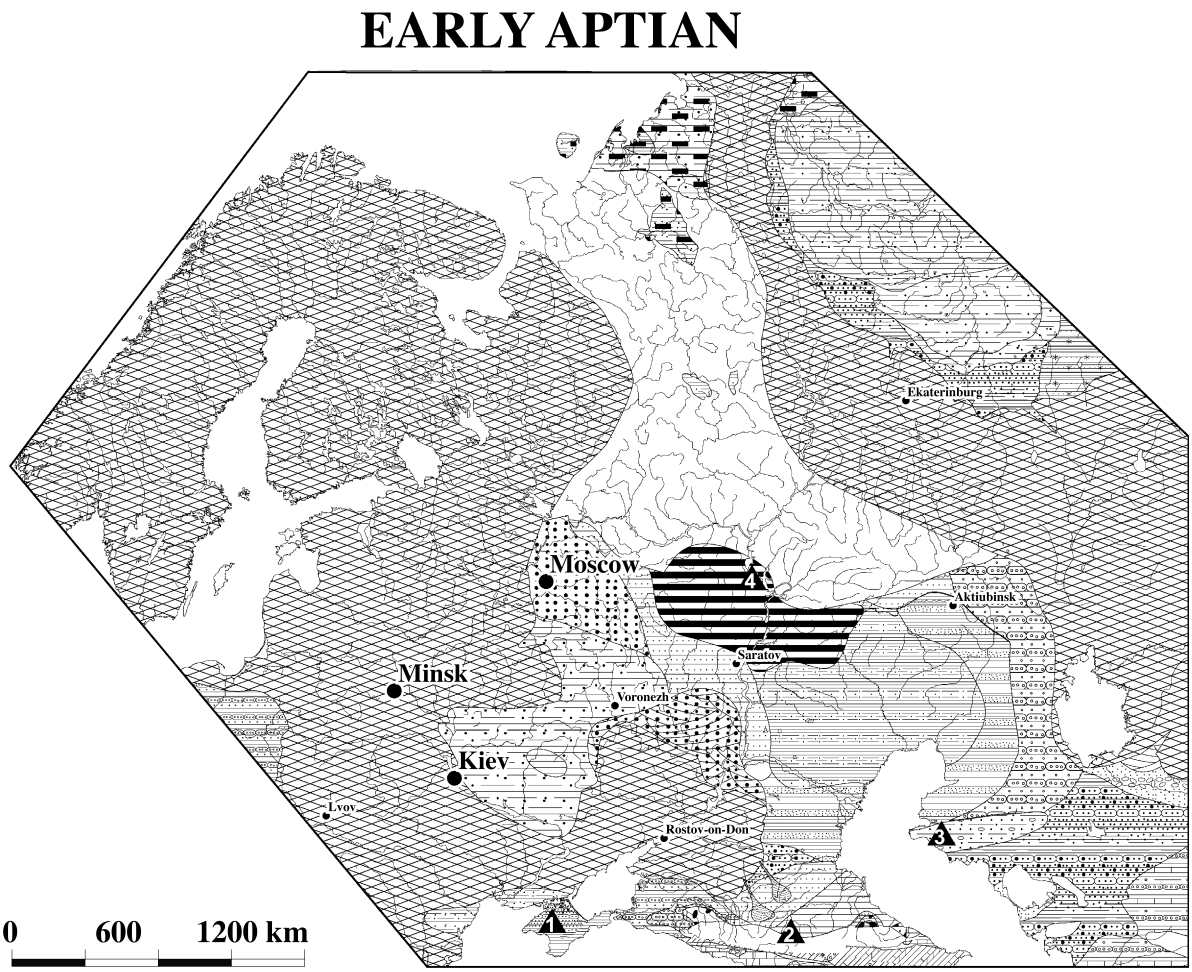


Fig. 4. Early Aptian palaeogeography of the North-Eastern Peri-Tethys. The legend is in Fig. 1.

area. Sedimentation in the Mangyshlak region started in the *Deshayesites weissi* Zone (Figs. 4 and 5), which is confirmed recently by rich ammonite assemblages (Bogdanova, 1999). At the same time the wide shallow sea-strait between the RP and the North Caucasus–Kopet-Dagh basins had been opened (Baraboshkin, 2001; Fig. 4). The history of the opening of this strait is documented in the RP sections by the appearance of Boreal *Deshayesites tenuicostatus–bodei* group (of North-European ancestry) above the fresh water interval in the basal Aptian (Baraboshkin et al., 1999, 2001). Later on, *Deshayesites volgensis*, European *D. saxbyi* Casey, *D.* aff. *vectensis* Spath and first Tethyan ammonites *Obsoleticeras levigatum* (Bogdanova) appeared in assemblage with small heteromorphs. This time coincides with the oil-shale deposition (Figs. 4 and 5) and stratification of the water column. The muddy sedimentation prevailed in the basin and it became deeper during the Early Aptian, which is reflected by the prevalence of heteromorph ammonites in the assemblages, which is reflected in the zonal scale (Mikhailova and Baraboshkin, 2001; Table 1). By the latest Early Aptian time (*Tropaeum bowerbankii* Zone) the shallowing of the basin has occurred and the basin regressed in southward direction.

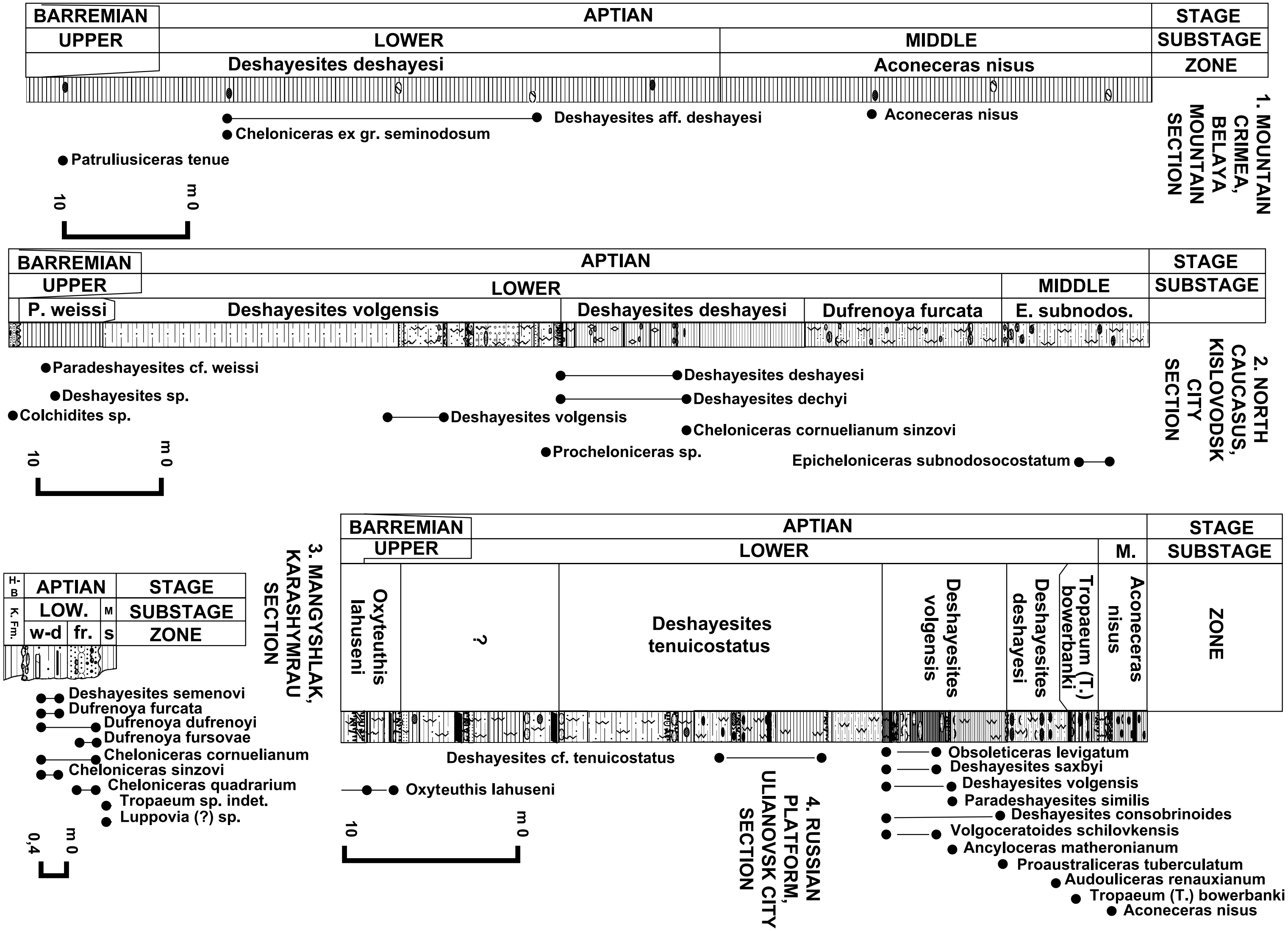


Fig. 5. Lower Aptian reference sections of the Crimea (1, Kacha River section, after Baraboshkin, 1997a), North Caucasus (2, Kislovodsk City section, E.Yu. Baraboshkin data), Mangyshlak (3, Karashymrau section, after Bogdanova, 1999) and the Russian Platform (4, Ulyanovsk City section, after Baraboshkin et al., 1999 with changes in Baraboshkin, 2001) and the key fauna distribution. Positions of the sections are marked with triangles in Fig. 4. The legend is in Fig. 1. The abbreviations for section 3: H-B = Hauterivian–Barremian, K. Fm. = Kugusem Formation, w-d = *Deshayesites weissi–Deshayesites deshayesi* Zone, fr. = *Dufrenoya furcata* Zone, s = *Epicheloniceras subnodosocostatum* Zone.

This tendency had continued during the Middle–Late Aptian, when the area of sedimentation moved in the Peri-Caspian area and continental conditions existed on most of the RP territory (Baraboshkin, 1996, 1997c; Baraboshkin et al., 1999). Almost uniform glauconite–quartz sands and clays deposited over the whole Caucasus–Kopet-Dagh region. Only in Mountain Crimea pelagic clayey sedimentation continued (Yanin and Vishnevsky, 1989).

In the Early Albian began a new stage in the development of Boreal and Tethyan realms. The RP basin developed as a shallow longitudinal sea-strait, which connected Boreal and Tethyan basins (Baraboshkin, 1996; Baraboshkin et al., 1998). A strong Boreal transgression marks an opening of this strait. This event could be traced by the distribution of the representatives of ammonite genus *Arcthoplites*, known in the Arctic Archipelago, Spitsbergen, North Greenland, Russian Platform, Mangyshlak, Central Iran (see references in Baraboshkin, 1996) and recently reported from England (Casey, 1999). Mountain Crimea uplifted and was affected by rifting and block movements (Nikishin et al., 1997) near the Aptian/Albian boundary or in the Early Albian. It was exposed as a highland unlike to Plain Crimea, where the shallow sea with terrigenous sedimentation has developed (Leschukh, 1987). In the Caucasus Albian clays transgressively with an unconformity at the base overlay older sediments (Baraboshkin, 1999a,b). The Aptian type of terrigenous sedimentation preserved in the Mangyshlak–Kopet-Dagh region, but the base of the Albian is marked by a phosphorite condensed bed almost everywhere there. The shallow basin of the RP filled with sandy cross-bedded lacustrine sands and near-shore glauconite–quartz sands. More fine clayey–sand sedimentation occurred in its central parts, especially in the Peri-Caspian (Baraboshkin, 1996). Simultaneously deltaic deposits of the eastern part of Peri-Caspian basin prograded westward because of the South Ural uplift and erosion. The sea also penetrated in the West Siberian basin in the Early Albian (Zakharov et al., 2000), but it had no connection with the RP basin.

During the end Middle–Late Albian the sea ingressed in the palaeovalleys of Mountain Crimea and filled them with clays and sands (Yanin and Vishnevsky, 1989). At the same time submarine middle volcanism started in Plain and South-Western Crimea (Leschukh, 1987), in the Black Sea and in the Small Caucasus. Volcanic tuff layers are good markers in the clayey sections of the Upper Albian of the North Caucasus (Baraboshkin, 1999a,b). In the Mangyshlak–Kopet-Dagh area the type of sedimentation preserved in general, but the sea became shallower and near-shore cross-bedded facies are widely distributed there. The developed large delta of the eastern Peri-Caspian prograded far to the south-west, but the North Caspian strait was not closed because of the sea-level rise. Nevertheless, the Boreal/Tethyan connection was interrupted, because the Mezen–Pechora strait in the north of RP closed in the Late Albian. It is confirmed by the absence of Boreal fauna, while the Tethyan ammonites and forams are known from the RP (Baraboshkin, 1996; Alekseev et al., 1996). Simultaneously, the south-eastern part of the RP was submerged almost completely (Moskvin, 1986–1987; Baraboshkin, 1996) and the new western seaway of RP was opened. At the beginning of the opening of this strait a condensed glauconite–quartz sand with phosphorites deposited all over the RP basin. In the Late Albian the eastern part of the RP basin deepened and clayey succession was formed there (Baraboshkin, 1996).

3. The Late Cretaceous

The Late Cretaceous palaeogeography of the North-Eastern Peri-Tethys was never extensively documented. Generalised stage maps for the Russian Platform were published by Sobolevskaya (1951) and Gerasimov et al. (1962). A few maps for several separate parts of this region are dispersed in other publications. More informative stage-by-stage maps for the complete North-Eastern Peri-Tethys area were published in two palaeogeographic atlases (Vinogradov, 1961, 1968). This was the only information available for Late Cretaceous palaeogeography for the whole region.

Table 2
Biostratigraphic scheme of the Upper Cretaceous of the North-Eastern Peri-Tethys (compiled by A.S. Alekseev, A.G. Olferiev and L.F. Kopaevich)

STAGE	SUBSTAGE	MACROFOSSIL ZONATION			BENTHIC FORAMINIFERAL ZONATION
MAASTRICHTIAN	UPPER	Hoploscaphites constrictus	Belemnitella junior - Neobelemnella kazimiroviensis		Brotzenella praeacuta - Hanzawaia ekblomi
MAASTRICHTIAN	LOWER	Hoploscaphites constrictus	Acanthoscaphites tridens	Belemnella sumensis	Brotzenella complanata
MAASTRICHTIAN	LOWER	Hoploscaphites constrictus	Acanthoscaphites tridens	Belemnitella lanceolata	Neoflabellina reticulata
CAMPANIAN	UPPER	Belemnella licharevi / Micraster grimmensis			Angulogavelinella gracilis
CAMPANIAN	UPPER	Belemnitella langei	Belemnitella langei najdini / Mictaster grimmensis		Globorotalites emdyensis
CAMPANIAN	UPPER	Belemnitella langei	Belemnitella langei langei / Didymoceras donezianum		Globorotalites emdyensis
CAMPANIAN	UPPER	Belemnitella langei	Belemnitella langei minor / Bostrychoceras polyplocum		Globorotalites emdyensis
CAMPANIAN	UPPER	Hoplitoplacenticeras coesfeldiense / Belemnitella mucronata mucronata			Brotzenella monterelensis
CAMPANIAN	LOWER	Bellemnellocamax mammilatus			Cibicidoides temirensis
CAMPANIAN	LOWER	Belemnitella mucronata alpha			Cibicidoides temirensis
CAMPANIAN	LOWER	Belemnitella parecursos mucronatiformis			Gavelinella clementiana clementiana
SANTONIAN	UPPER	Sphenoceramus patootensis / Belemnitella praecursor praecursor			Gavelinella stelligera
SANTONIAN	LOWER	Texanites texanus / Sphenoceramus cardissoides / Belemnitella propinqua			Gavelinella infrasantonica
CONIACIAN	UPPER	Magadiceramus subquadratus			Gavelinella thalmanni
CONIACIAN	MIDDLE	Volviceramus involutus			Gavelinella thalmanni
CONIACIAN	MIDDLE	Volviceramus koeneni			Gavelinella thalmanni
CONIACIAN	LOWER	Cremnoceramus crassus - Cremnoceramus deformis Cremnoceramus brogniarti Cremnoceramus rotundatus			Gavelinella kelleri
TURONIAN	UPPER	Mytiloides scupini - Mytiloides incertus			Gavelinella moniliformis
TURONIAN	UPPER	Mytiloides striatoconcentricus			Gavelinella moniliformis
TURONIAN	UPPER	Inoceramus costellatus			Gavelinella moniliformis
TURONIAN	MIDDLE	Inoceramus lamarcki			Gavelinella moniliformis
TURONIAN	MIDDLE	Inoceramus apicalis			Gavelinella moniliformis
TURONIAN	MIDDLE	Mytiloides hercynicus			Gavelinella moniliformis
TURONIAN	LOWER	Mytiloides labiatus - Mytiloides kossmati / Actinocamax plenus triangulus			Gavelinella nana
CENOMANIAN	UPPER	Inoceramus pictus bohemicus ó Inoceramus pictus pictus / Actinocamax plenus longus			Lingulogavelinella globosa
CENOMANIAN	MIDDLE	Acanthoceras rhotomagense / Inoceramus crippsii			Lingulogavelinella globosa
CENOMANIAN	LOWER	Turrilites costatus - Schloenbachia varians / Actinocamax primus primus - Neohibolites ultimus / Inoceramus crippsii			Gavelinella cenomanica

3.1. Stratigraphic schemes

The stratigraphy of the Upper Cretaceous on the Russian Platform, the Crimea, the Scythian and Turanian platforms is traditionally based on the Western European standard because of the similarity of taxonomic composition of Late Cretaceous marine faunas of these regions with those from northern Europe. Therefore the North-Eastern Peri-Tethys is included in the European palaeogeographic province (Naidin, 1969; Alekseev, 1989; Beniamovskii and Kopaevich, 1998).

The lithostratigraphy is not firmly developed yet for many regions of the North-Eastern Peri-Tethys and local formations, which were proposed a few years ago, are not published yet or have a very limited usage.

The biostratigraphic scheme is based mainly on inoceramids and belemnites for the Cenomanian–Coniacian interval and on belemnites for Santonian–Maastrichtian interval (Table 2). The ammonite fauna is not very abundant in this area. It is mainly known from the Crimea (Moskvin, 1959; Marcinowski, 1980; Alekseev, 1989; Gale et al., 1999; Arkadiev et al., 2000), Peri-Caspian (Sobetsky et al., 1982), Mangyshlak (Semenov, 1899; Marcinowski et al., 1996; Gale et

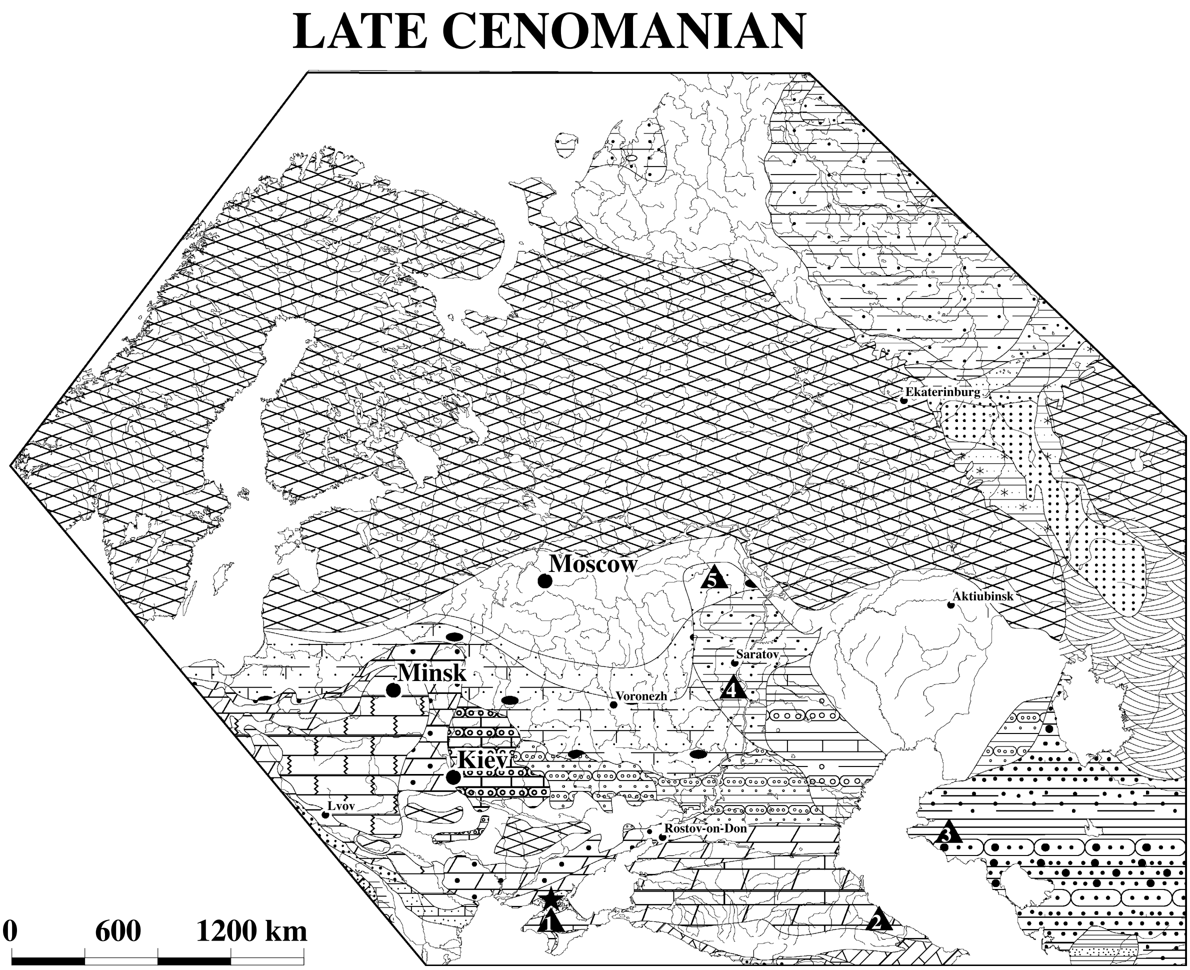


Fig. 6. Late Cenomanian palaeogeography of the North-Eastern Peri-Tethys. The legend is in Fig. 1.

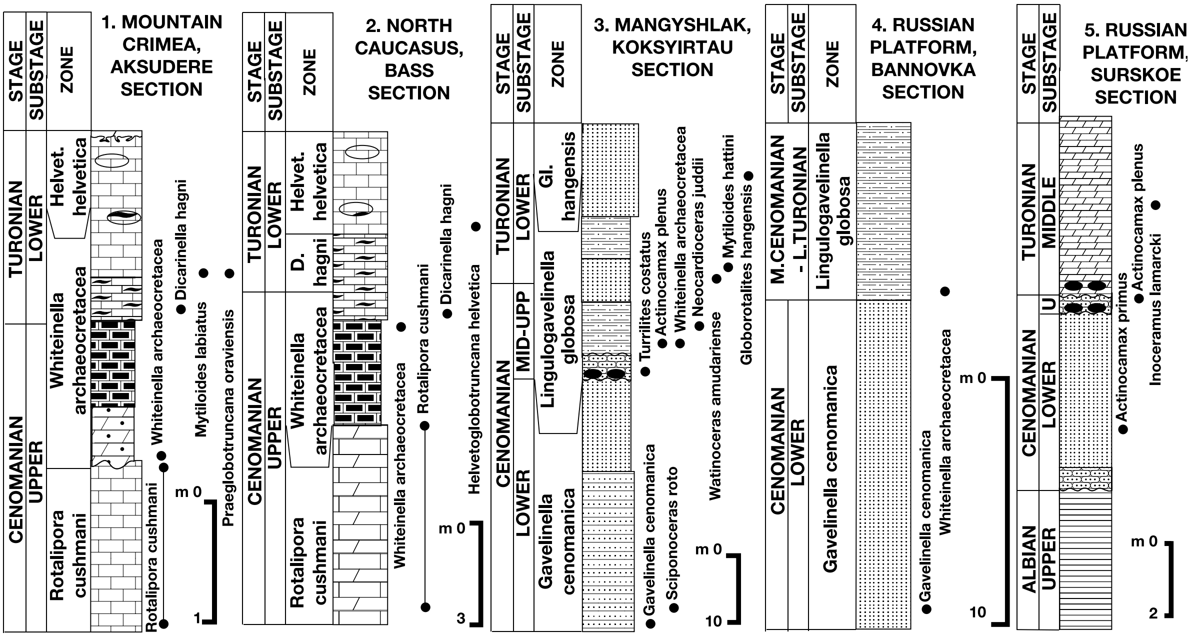


Fig. 7. Upper Cenomanian reference sections of the Crimea (1, Aksudere section, after Alekseev et al., 1997), North Caucasus (2, Bass section, after Tur, 1994), Mangyshlak (3, Koksyirtau section, after Naidin et al., 1984) and the Russian Platform (4, Bannovka section, A.G. Olferiev and L.F. Kopaevich data and 5, Surskoe section, after Glazunova, 1972) and the key fauna distribution. The positions of the sections are marked with triangles in Fig. 6. The legend is in Fig. 1.

al., 1999) and Donbass (Krymholtz, 1974). Because of their rarity ammonites are not very useful for zonal subdivision and correlation of this area.

The most important group for biostratigraphy of the region are benthic foraminifera, for which a detailed zonation was proposed recently (Beniamovskii and Kopaevich, 1998). The planktonic foraminiferal associations with Tethyan affinity are known only from the Crimea and from the North Caucasus (Maslakova, 1978; Samyshkina, 1983; Tur, 1994). Calcareous nannoplankton dating was done for a few sections only and still needs further work.

We discuss the stratigraphic position only for those Upper Cretaceous time-slices, which were used for the Peri-Tethys maps.

The Upper Cenomanian was identified by planktonic foraminifera for deep-water successions of the Crimea and North Caucasus (Maslakova, 1978), and by benthic foraminifera and belemnites for RP and Mangyshlak (Naidin et al., 1984). The Late Cenomanian ammonite index (*Neocardioceras juddii*) was found (Marcinowski et al., 1996) only in Mangyshlak.

The Upper Cenomanian of the RP is strongly condensed and represented only by reworked phosphorites or may even be missing completely (Baraboshkin et al., 1998; Fig. 6). Calcareous sands sometimes contain phosphatic nodule horizons. These sediments contain only few fossils. The Upper Cenomanian is dated mainly by the belemnite *Actinocamax plenus*, the benthic foraminifer *Lingulogavelinella globosa* and the calcareous nannofossil *Microrhabdulus decoratus*. However the FO of two latter taxa is in the Middle Cenomanian. Only from a few sections the *Whiteinella archaeocretacea* Zone could be identified. The thickness of the Upper Cenomanian is not more than 2–4 m. In the Surskoe section (Ulyanovsk region) the Upper Cenomanian is represented by glauconitic sand (0.6 m) with phosphatic nodules and *A. plenus* rostra (Glazunova, 1972) (Fig. 7).

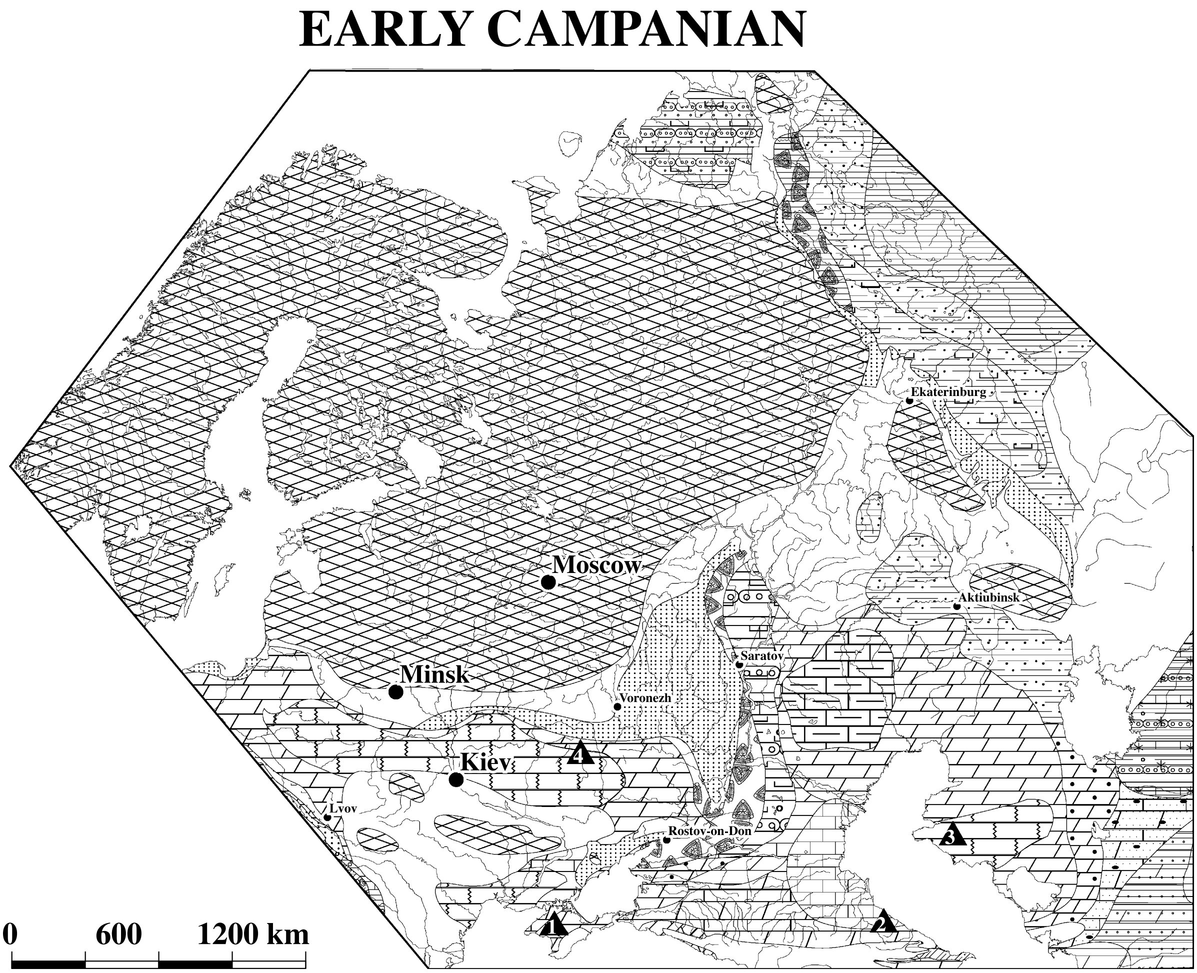


Fig. 8. Early Campanian palaeogeography of the North-Eastern Peri-Tethys. The legend is in Fig. 1.

The Cenomanian of the Crimea is represented by limestones and marls (50–70 m) and the Upper Cenomanian by white limestones with rare marl intercalations (0.5–1.0 m). The thickness of the Upper Cenomanian varies from 10 up to 20 m (Alekseev et al., 1997; Kuzmicheva, 2000, 2001). There is considerable lateral variation of the succession overlying the Upper Cenomanian. Highly condensed Lower Turonian glauconitic marls lay directly upon the erosional surface in most sections. In the most complete – the Aksudere section – brown clays and organic-rich, brown and dark-grey laminated marls (1–1.5 m) with quartz, glauconite and volcanic silt material, fish remains and *Chondrites* bioturbations are present (Fig. 7). This interval belongs to the *Whiteinella archaeocretacea* Zone and is interpreted as the local representation of the Late Cenomanian 'Oceanic Anoxic Event 2' (Alekseev et al., 1997; Kopaevich, 1996; Gale et al., 1999). The position of the C/T boundary can be determined by the appearance of *Dicarinella hagni* (Scheibnerova), as in the other Peri-Tethys regions (Kopaevich and Walaszczyk, 1990; Salaj, 1996; Kuzmicheva, 2001).

The Cenomanian of the North Caucasus is represented by rhythmically bedded marly limestones and marls in Daghestan and carbonate turbidites or pelagic periodites in the western part of the

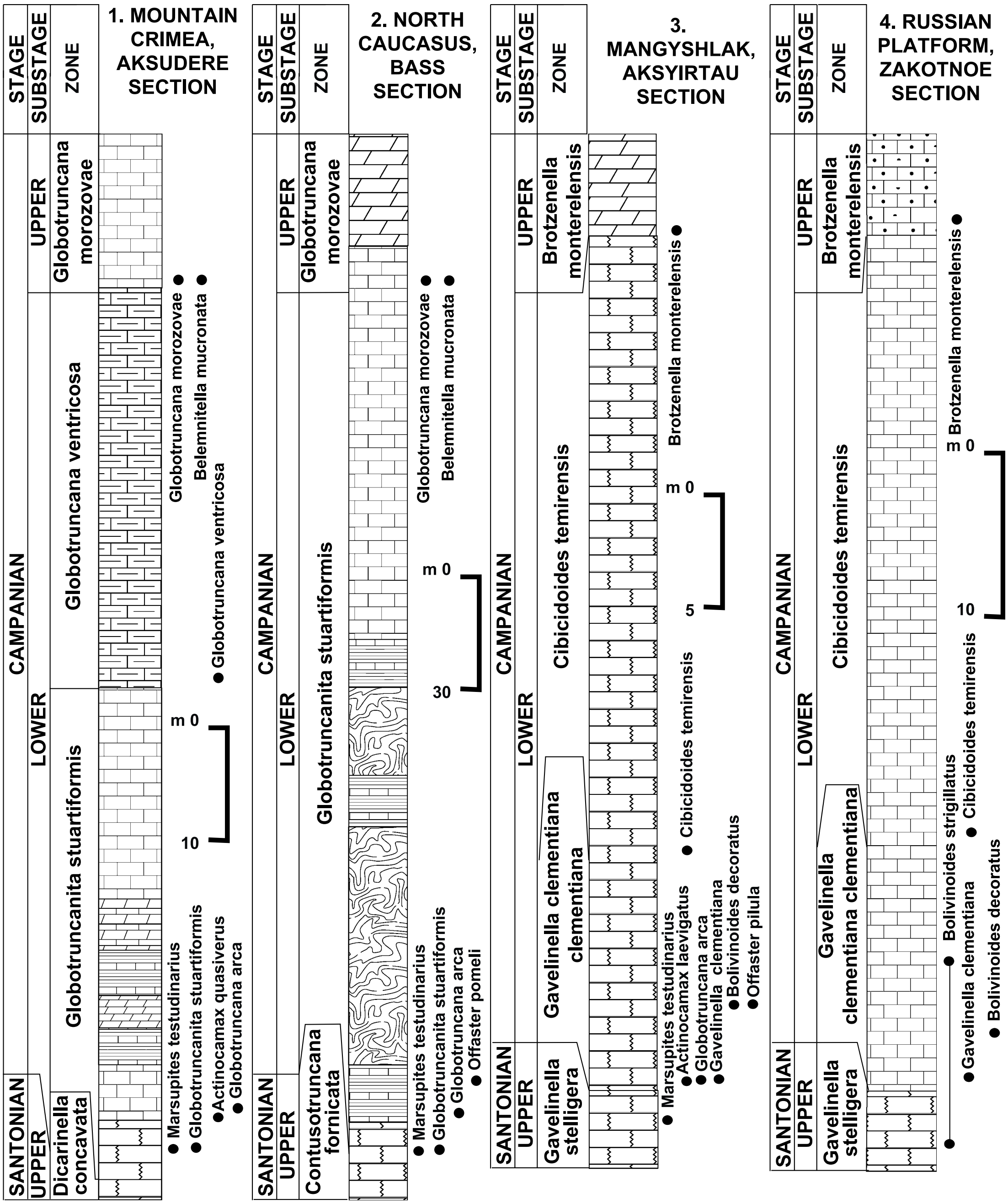


Fig. 9. Lower Campanian reference sections of the Crimea (1, Aksudere section, after Alekseev, 1989), North Caucasus (2, Bass section, after Aliev and Mirkamalov, 1986), Mangyshlak (3, Aksyirtau section, after Kopaevich and Beniamovskii, 1999) and the Russian Platform (4, Zakotnoe section, after Naidin and Ivannikov, 1980) and the key fossil distribution. The positions of the sections are marked with triangles in Fig. 8. The legend is in Fig. 1.

Great Caucasus. The latter also contains the Lower Turonian black shale Annanur Formation. Within the Upper Cenomanian sequence in the eastern part of North Caucasus (Bass section) two units are distinguished: the grey marly limestones with bentonites and light-coloured limestones with several layers of black marl and flint concretions near the Cenomanian–Turonian boundary (Tur, 1994). As for the Crimea this interval is interpreted as 'black shale' facies and a representation of the Late Cenomanian 'Oceanic Anoxic Event 2'.

The Tethyan foraminiferal zonation (Caron, 1985; Robaszynski and Caron, 1995) is recognised in the Bass section. We can identify the *Rotalipora cushmani* Zone (Middle–Upper Cenomanian). The extinction of *Rotalipora* is the upper marker level of this biostratigraphic unit. The genus *Rotalipora* disappears before the end of the Cenomanian in the *Metoicoceras geslinianum* Zone in the Mediterranean area (Robaszynski and Caron, 1995). The next zone, the *Whiteinella archaeocretacea* Zone, includes the interval from the last of *R. cushmani* to the first of *Helvetoglobotruncana helvetica*. The C/T boundary is situated within the *W. archaeocretacea* Zone and its position can be determined by the appearance of *Dicarinella hagni* (Scheibnorova) (Tur, 1994).

The Cenomanian in the Mangyshlak Peninsula comprises 5–50 m of sands, silts, marls and thin phosphatic conglomerates. The Upper Cenomanian is only identified in the Koksyirtau and Aksyirtau sections (Jolkichev and Naidin, 2000). In the other parts of Mangyshlak the Middle and Upper Cenomanian fossils are found in the phosphatic conglomerate at the base of Turonian sands.

The Upper Cenomanian Koksyirtau section is represented by fine sands, silt and clays (8 m), the lower part of which (4 m) is dark-grey, weakly to strongly laminated and contains up to 5% C_{org}. These organic-rich silts and laminated fine sands are interpreted as a local 'Oceanic Anoxic Event 2' (Gale et al., 1999). An epibol of the belemnite *Actinocamax plenus* (Blainville) is probably correlated with the acme zone of the species in the Anglo-Paris basin (Jefferies, 1963) within the *Metoicoceras geslinianum* Zone (Wright and Kennedy, 1981). In 2.7 m above the *A. plenus* horizon Marcinowski et al. (1996) found *Neocardioceras juddii* (Barrois et Guerne), the index-species of the uppermost Cenomanian ammonite Zone. 4 m above this level Marcinowski et al. (1996) recorded *Watinoceras amudariense* (Arkhangelsky), index-species for the Lower Turonian. The uppermost part of the Cenomanian is characterised by abundant specimens of planktonic foraminifera including the large *Hedbergella–Whiteinella* of *Whiteinella archaeocretacea* Zone (Kopaevich et al., 1999).

The Lower Campanian is widespread all over the studied area and represented by transgressive series of carbonate sediments. The base of the Campanian is different in different localities: it can be very sharp with a hiatus, or with a small condensation, or it can be represented by a continuous transition with the Upper Santonian.

The Lower Campanian is widespread on the Russian Platform. These sediments have a relatively high thickness and are mainly carbonates (marls, chalks and sandy chalks: Fig. 8).

The Lower Campanian contains abundant belemnites and benthic foraminifera typical also for Western Europe (Schönfeld, 1990; Schönfeld and Burnett, 1991). The Santonian/Campanian boundary is partly problematic due to the controversial position of so-called 'Pteria-beds' and was placed inside the *Bolivinoides strigillatus* foraminiferal Zone (BF2) (Beniamovskii and Kopaevich, 1998). For age determination we used the benthic foraminiferal zonation of the European palaeobiogeographic province (Beniamovskii and Kopaevich, 1998). The Lower Campanian interval consists of two zones – *Gavelinella clementiana clementiana* (BF3) and *Bolivinoides decoratus decoratus* (BF4).

One of the reference sections of the Lower Campanian of RP is Zakotnoe village in the Donetsk region (Fig. 9). The Lower Campanian succession includes marls and chalk (15 m) with typical foraminiferal assemblages and the belemnite *Gonioteuthis quadrata* (Naidin and Ivannikov, 1980).

Campanian sediments are widespread in the Crimea. They are relatively thick (up to 400 m) and consist of carbonate rocks (marls, chalky

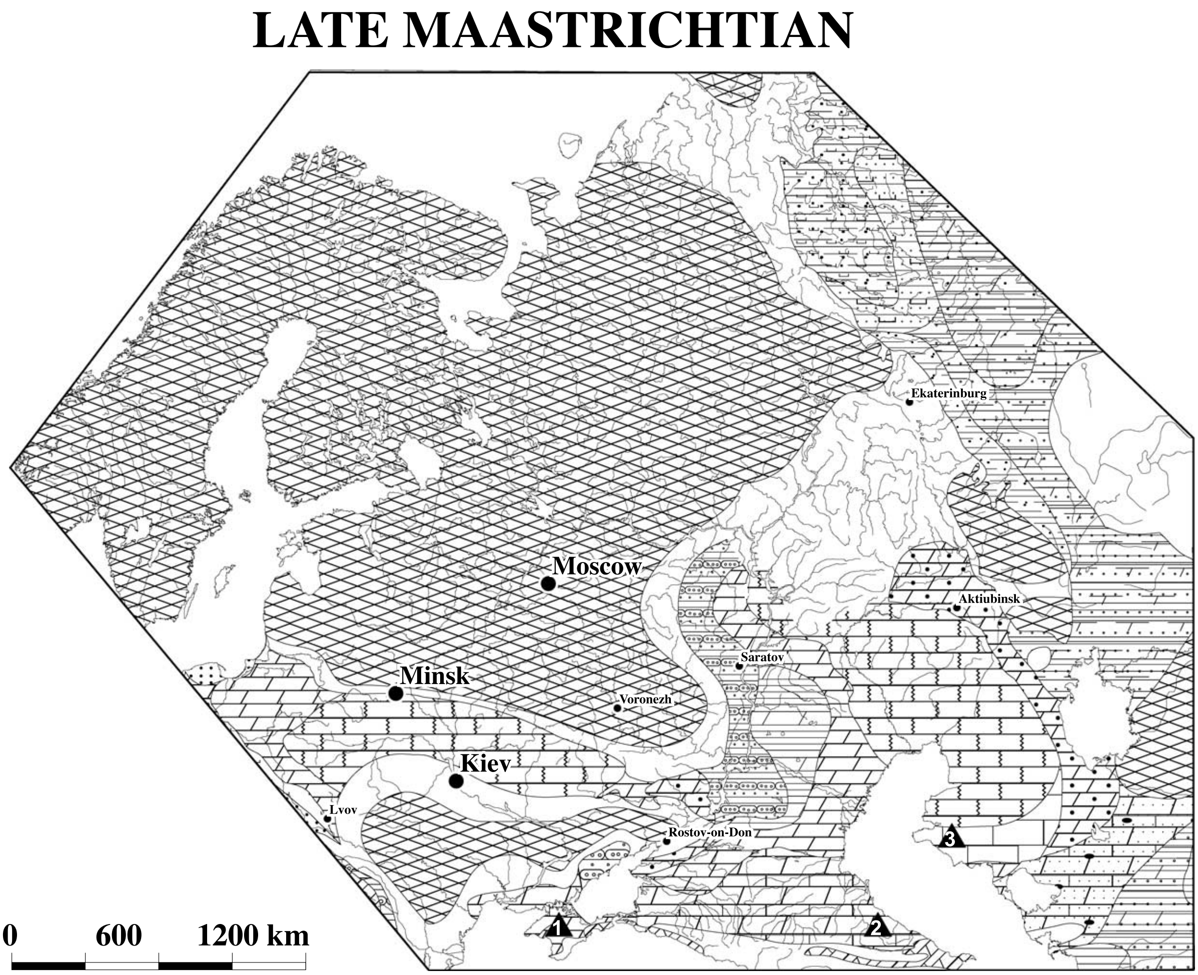


Fig. 10. Late Maastrichtian palaeogeography of the North-Eastern Peri-Tethys. The legend is in Fig. 1.

marls) with belemnites, inoceramids, planktonic and benthic foraminifera also known from Western Europe. The lowest Campanian beds transgressively overlie different horizons: Upper Albian to Upper Santonian. The Lower Campanian is represented by an alternation of grey or green-grey marls and white limestones with rare black flint nodules in the South-Western Crimea. The total thickness of this unit is 50–90 m. There are no index macrofossils in the Aksudere reference section near Bakhchisaray town. Only a few rostra of *Actinocamax quasiverus* Naidin, *Gonioteuthis* sp., and also *Inoceramus azerbaydjanensis* Aliev, *Inoceramus brancoi* Wegner, *Inoceramus muelleri* Petrascheck were found. However foraminiferal and nannofossil data certainly confirm the Early Campanian age of these marls: they contain assemblages of *Globotruncanita stuartiformis* Zone (planktonic foraminifera) and *Arkhangelskiella specillata* Zone (nannofossils).

The Lower Campanian of the North Caucasus is build up by an alternation of white limestones and grey or green-grey clayey limestones and marls. The total thickness is 50–90 m in Daghestan. In the Bass section the Lower Campanian contains belemnites, inoceramids, echinoids and rare ammonites. The foraminiferal zonation is

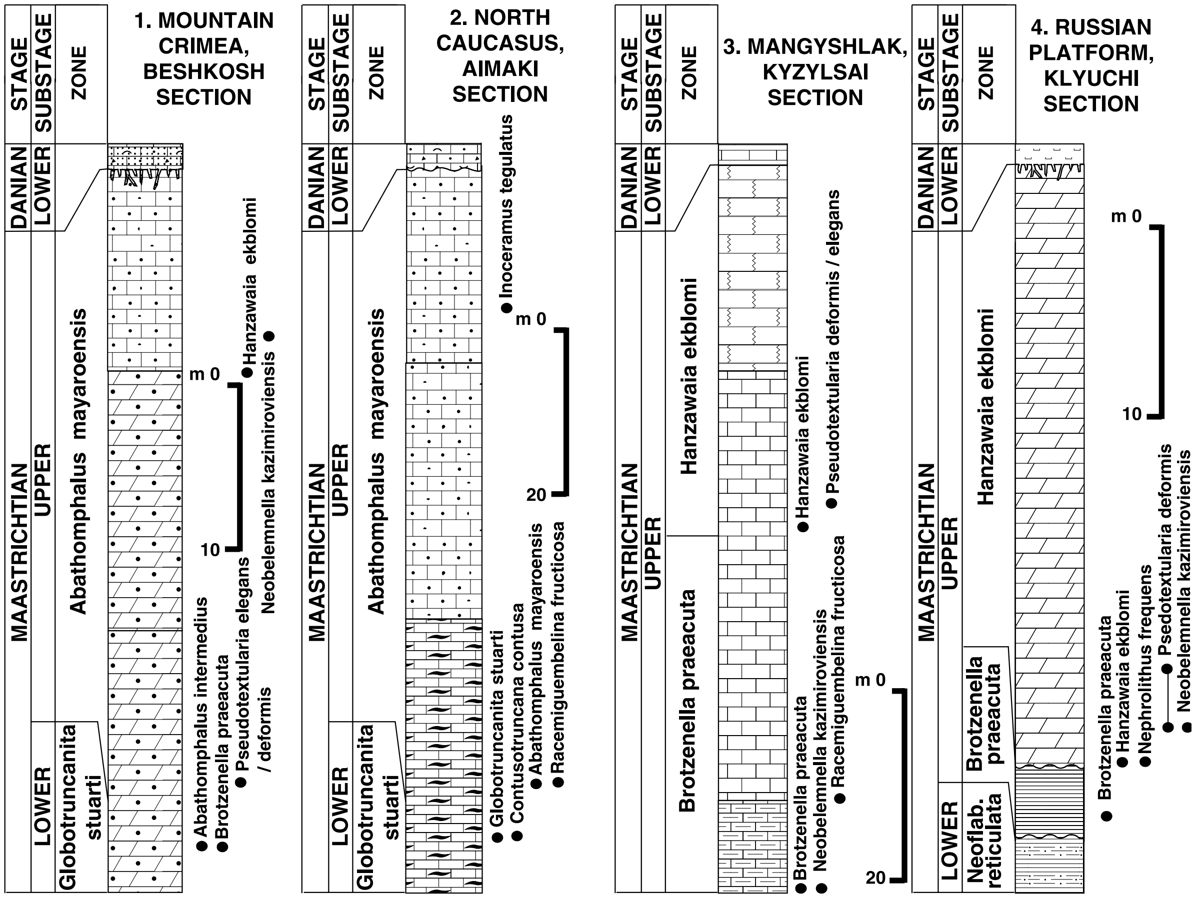


Fig. 11. Upper Maastrichtian reference sections of the Crimea (1, Beshkosh section, after Alekseev and Kopaevich, 1997), North Caucasus (2, Aimaki section, after Aliev and Mirkamalov, 1986), Mangyshlak (3, Kyzylsai section, after Naidin et al., 1984) and the Russian Platform (4, Klyuchi section, after Alekseev et al., 1999) and the key fauna distribution. Positions of the sections are marked with triangles in Fig. 10. The legend is in Fig. 1.

the same as in the Crimea (Aliev and Mirkamalov, 1986).

The Campanian is represented by pure white chalk and chalky marls in Mangyshlak. The lower boundary of the Campanian coincides with the disappearance of *Marsupites testudinarius* (Schlotheim). Many small echinoids (*Offaster* and *Galeola*) are found in the lower part of Campanian (Kopaevich et al., 1999). The base of the Upper Campanian cannot be precisely fixed. However, the appearance of *Belemnitella mucronata* (Schlotheim) and of the benthic foraminifer *Brotzenella monterelensis* (Marie) could be used as proxy to mark this boundary. The foraminiferal assemblages from the Lower Campanian are practically identical with those from RP. The characteristic section for the Lower Campanian is Aksyirtau (Fig. 9).

The area occupied by Maastrichtian marine sediments is almost the same as for the Campanian in North-Eastern Peri-Tethys. The base of the Maastrichtian contains a hiatus in marginal facies of the basin. Two transgressive impulses are recognised – the earliest Maastrichtian and the early Late Maastrichtian. Most of the sections have a hiatus at the Maastrichtian/Danian boundary. Only the Koshak and Kyzylsai sections (Northern Mangyshlak) show a gradual transition with 'boundary clay' formation. An iridium anomaly was found in the clays (Naidin et al., 1984).

Upper Maastrichtian facies are more variable because of tectonic activity on the RP and adjacent structures (Nikishin et al., 1999; Fig. 10). Late Maastrichtian was the time of regression in the Russian Platform and in many regions sediments of this age were later eroded. Sedimentation was confined mainly to the Dnieper-Donets Depression (chalks), the Volga River region and the Peri-Caspian Depression, where transition from coastal clastic facies in the west to the chalk facies in the east has occurred. The Upper Maastrichtian reference Klyuchi section in the Saratov region (Alekseev et al., 1999) consists of calcareous clays and chalky marls (13–15 m, Fig. 11). The interval was identified by benthic foraminifera from the *Brotzenella praeacuta* and *Hanzawaia ekblomi* Zones (BF12–BF13), *Neobelemnella kazimiroviensis* Zone (belemnite) and *Nephrolithus frequens* Zone (nannofossils). The correlation with north Western Europe is very precise.

The Maastrichtian occurs throughout the Crimea Peninsula. It has a relatively high thickness (up to 800 m in Plain Crimea), and is represented by carbonate rocks (silty limestones, marls and chalky marls) with abundant belemnites, inoceramids, planktonic and benthic foraminifera characteristic for Western Europe. The Late Maastrichtian was a regressive time in the south-western part of Mountain Crimea. The Upper Maastrichtian regressive sequence there consists of sandy marls, calcareous sandstones and sandy limestones with numerous oyster horizons. At the same time more pelagic rhythmic marls and siltstones accumulated in the basin of Eastern Crimea. The total thickness of the Upper Maastrichtian varies from 0 to 200 m.

The following Late Maastrichtian index fossils are present in the Crimea reference Beshkosh section (Alekseev and Kopaevich, 1997; Fig. 12): *Neobelemnella kazimiroviensis* (Skolozdrowna), *Pachydiscus* ex gr. *neubergicus*. Oysters are abundant and other bivalves occur frequently, especially *Pycnodonte vesicularis* (Sowerby), *Pycnodonte mirabilis* (Rousseau), and *Microchlamys acuteplicata* (Alth).

The *Nephrolithus frequens* Zone (nannofossils) was identified from this section. On the basis of the benthic foraminifera distribution the *Brotzenella praeacuta* Zone (BF12) and *Hanzawaia ekblomi* Zone (BF13) were recognised (Alekseev and Kopaevich, 1997). The general taxonomic composition of benthic foraminiferal assemblages is very similar to those from northern Europe (Robaszynski et al., 1985; Robaszynski and Christensen, 1989; Schönfeld, 1990). Turbiditic facies of Eastern Crimea contain mainly planktonic foraminiferal assemblages typical for the *Abathomphalus mayaroensis* Zone.

The Upper Maastrichtian interval is well exposed in the Betta section, situated in the Novorossyisk synclinorium along the Black Sea shore (western part of the North Caucasus). Rocks are represented by pelagic flysch and periodite alternation of sandstones, marls and limestone intercalations (450–500 m) (Gabdullin et al., 1999). According to planktonic foraminifera data the age of the succession is *Abathomphalus mayaroensis* Zone and according to nannoplankton is *Arkhangelskiella cymbiformis* (CC25) zone and *Micula murus* (CC25c) subzone.

Maastrichtian rocks are widespread in Daghestan in the eastern part of the North Caucasus. The succession (80–90 m) is represented by rhythmically bedded limestones and clayey limestones with detritic interlayers and slumping structures. Many fossil remains occur in this unit: ammonites, belemnites, brachiopods, echinids, but especially inoceramids, which were used for the zonation (Aliev and Mirkamalov, 1986; Walaszczyk et al., 1996). The planktonic foraminiferal zonation is represented by the *Abathomphalus mayaroensis* Zone (Samyshkina, 1983) or the *Racemiguembelina fructicosa* Zone (Botvinnik, 1982).

The Maastrichtian chalk of Northern Mangyshlak has a thickness of 140–150 m. The white chalks are intercalated with yellowish-brown marls and contain numerous hardground horizons. In the more complete sections the K/T boundary is marked by a 1–4 cm thick green layer, with remarkably sharp boundaries with the carbonates above and below. In the axial part of the Mangyshlak Mountains more shallow water marls, sandy marls and bioclastic lime-

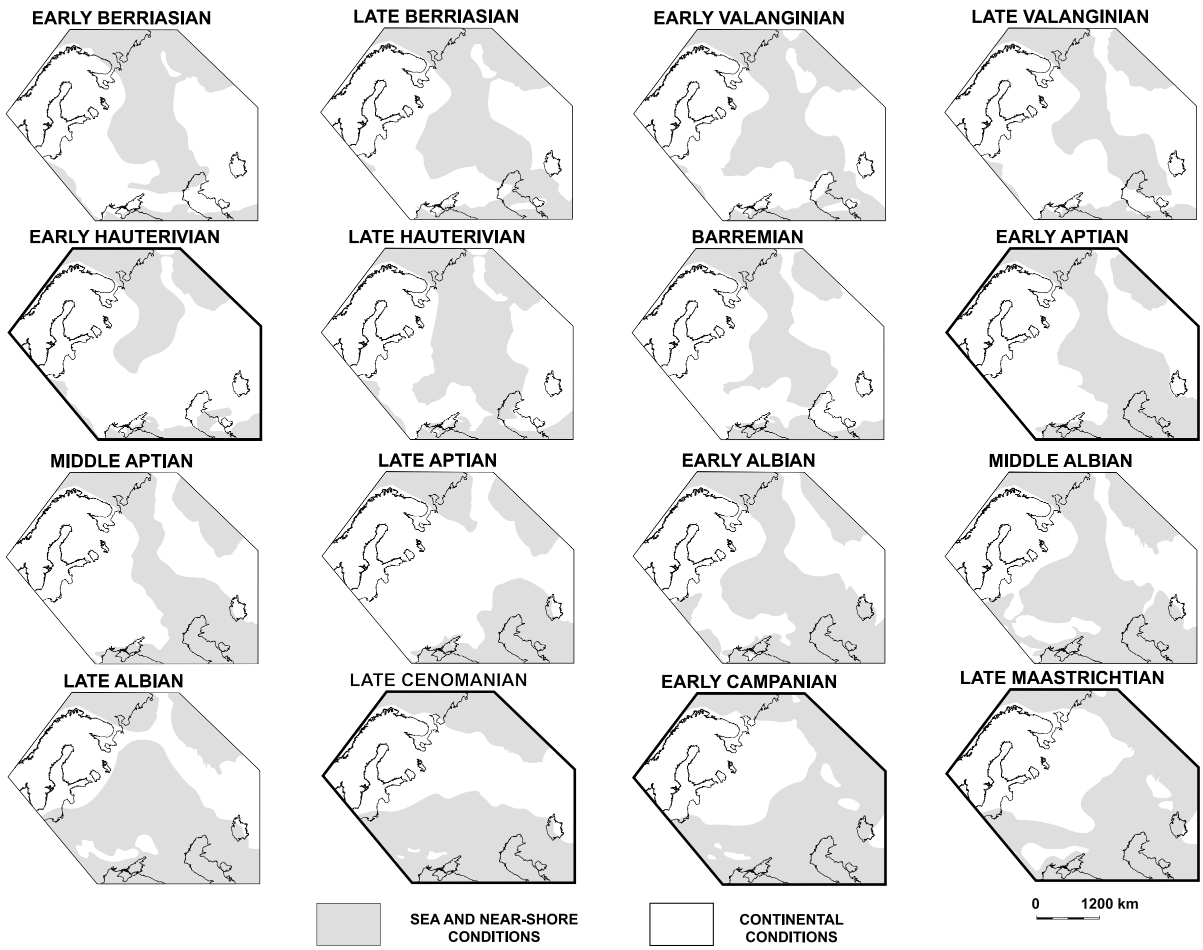


Fig. 12. Scheme of the development of the sea/continental conditions in the North-Eastern Peri-Tethys during the Cretaceous (after Baraboshkin, 1997c, changed and completed).

stones with clastic materials occur in the Upper Maastrichtian (50–80 m). It contains rich assemblages of macrofossils: ammonites *Hoploscaphites constrictus constrictus* (J. Sowerby), *H. constrictus crassus* (Lopuski); belemnites *Neobelemnella kazimiroviensis* (Skolozdrowna); echinids *Cyclaster integer* Seunes, *Echinocorys ciplyensis* Lambert, *Echinocorys arnaudi* Seunes, *Echinocorys meudonensis* Lambert, *Echinocorys pyramidata* Portlock, *Gauthieria radiata broecki* Lambert and *Salenidia pygmea* (von Hagenow). The Upper Maastrichtian chalk contains very rich assemblages of benthic foraminifera. On the basis of their distribution the *Brotzenella praeacuta* Zone (BF12) in the lower part and *Hanzawaia ekblomi* Zone (BF13) in the upper part of the succession were recognised (Naidin et al., 1984; Beniamovskii and Kopaevich, 1998; Kopaevich and Beniamovskii, 1999). Planktonic foraminifera assemblages in the Upper Maastrichtian of Mangyshlak show a low diversity. However, the presence of some zonal species allows to recognise the upper part of *Globotruncanita stuarti* Zone and *Pseudotextularia elegans* (= *deformis*) Zone (Kopaevich and Beniamovskii, 1999). Calcareous nannofossils include *Nephrolithus frequens* (Gorka), the marker species for the Upper Maastrichtian in high latitudes (Herman et al., 1988; Naidin et al., 1990; Kopaevich and Beniamovskii, 1999).

3.2. Major palaeogeographic changes

The marine basin that occupied the southern part of the Russian Platform, the Crimea, Scythian and Turanian platforms during Late Cretaceous times was relatively shallow water northern periphery of Tethys. This sea had connections with a West Siberian cold sea through narrow straits crossing the Urals in its lower parts and through the relatively wide, but very shallow Turgay Strait east of Ural Mountains. The marine basin under discussion was opened to the south and connected with the deep-water Caucasus Trough with flysch sedimentation. Connections with marine basins of North Europe existed constantly through the Dnieper-Donets Depression and Lvov basin. Some weak faunal and sedimentological evidence exists that periodically water exchange occurred with marine basin of the Barents Sea and the Timan–Pechora region. The seaway could have passed through the central part of the Moscow basin, but all sediments of this age were eroded in Cenozoic.

Southern part of the RP was covered with a shallow marine basin with dominantly terrigenous clastic sedimentation during the Cenomanian. In the northern part of the basin a shallow wide siliciclastic belt of several hundreds kilometres occurs. The Upper Cenomanian sediments were eroded during the latest Cenomanian–Early Turonian regression on the RP. Only a few metres of limestones with phosphate nodules at its top occur there. In the Dnieper-Donets Depression sandy marls accumulated. The Ukrainian Crystalline Shield and the Donets basin constitute a lowland. In the western Ukraine and in Moldavia in Late Cenomanian times carbonate sediments with inoceramid shell debris and sand material were accumulated (Fig. 6). At the northern margin of the Black Sea the Upper Cenomanian is represented by sandy limestones and marls. There is no evidence of the presence of Upper Cenomanian for the Peri-Caspian Depression. In the western part of this structure Turonian clastic sediments and marls overly Lower Cenomanian sands. Most probably Upper Cenomanian sediments were eroded in the Early Turonian.

The Upper Cenomanian of the Mangyshlak is represented in a few complete sections. A shallow water marine basin with a clastic sedimentation existed there. A very reduced sedimentation seems to clearly mark a regressive episode (Marcinowski et al., 1996), but the uppermost part of this interval is interpreted as a transgressive impulse and corresponds with OAE event (Gale et al., 1999).

In South-Western Crimea during the Late Cenomanian interval a deep-water (500–700 m according to planktonic/benthic foraminifera ratio) basin existed. The short terminal Cenomanian interval is relatively regressive, but the next one uppermost Cenomanian represents a transgressive impulse. The same situation existed in the North Caucasus area with deeper-water conditions in the western part of the Great Caucasus basin (turbidites and deep-water periodites).

During the Early Turonian the erosion resulted in a sea-level fall in most regions of the RP, Scythian and Turanian platforms. Only in southernmost areas did the sedimentation continue. The next transgressive episode began in the Middle Turonian with a maximum in the Late Turonian and Coniacian (Kopaevich, 1996). Northward from Moscow (57°N) calcareous clays with benthic foraminifera and nannofossils accumulated during this time. Everywhere this time interval is represented by relatively pure carbonates (chalks, marls, etc.). Santonian commonly overlay older rocks with disconformity and erosion hiatus. The siliciclastic sedimentation (siliceous clays and diatomites) has started in the Santonian in the northern part of the basin.

The Early Campanian was an episode of the widest transgression on the RP during the Late Cretaceous (Fig. 8). A coastline passed in the latitudinal direction to the north from Bryansk, Kursk and Voronezh. To the south of this coastline the wide belt of phosphatic sands and sandy marls existed. Between recent Don and Volga rivers a thick terrigenous avandelta was recognised. This deltaic complex belongs to a large river system, which flows from the northwest close to valley of modern Don River. Influence of this delta is traced to the south (up to the Stavropol area in Peri-Caucasus: Moskvin, 1962) by a wide belt of siliciclastic sediments, which was formed due to the high productivity of diatoms as a result of fresh water supply.

The area of deeper-water marly and chalky sedimentation was placed in the Peri-Caspian Depression. On its western and eastern margins a narrow belt of sandy and clay sedimentation existed. The position of the coastline in the north-eastern part of Peri-Caspian Depression is not known because of subsequent erosion. However, a narrow strait crossing the very low Uralian Mountains at the latitude of Orenburg and Orsk existed. This strait connected the RP marine basin with the Western Siberian one. Another strait connected the Tethys with the Western Siberian basin in the Turgay lowland and the cool/warm water exchange is recognised for this region by the foraminiferal data.

At the northern coast of Black Sea carbonate facies have accumulated: chalks in the western part and marls/limestones in the eastern part. Mountain Crimea and the most part of North Caucasus was the area of deeper-water marly sedimentation. The eastern part of the Pre-Caucasus and south part of the Turanian Platform regions were covered by relatively deep-water chalks and chalky limestones. Only in southernmost part of Turanian Platform (around Karabogaz) the more deep-water marl accumulation took place.

There were no serious changes in the marine basin configuration during the Late Campanian to Early Maastrichtian. However sea-level fluctuations gave rise to hiatuses over the RP and tectonic activity increased uplifts in the marginal part of the RP. These uplifts were active during the Maastrichtian (Nikishin et al., 1999) and they affected local sedimentation (Alekseev et al., 1999).

The Late Maastrichtian (Fig. 10) was a regressive phase on the RP. The north coastline moved to the south over several hundred kilometres, but sediments of coastal parts of the basin were eroded later. The Dnieper-Donets marine basin had connections in the west with the Polish basin through Western Ukraine. The Proto–Don river system continued to be active, but the deltaic wedge became narrower. The Ukrainian Shield and Donets basin were united in a single block of lowland as a result of uplift. Pure carbonates accumulated in the northern part of the Black Sea basin during Late Maastrichtian. In a very shallow warm marine basin in South-Western Crimea (close to Bakhchisaray) calcareous sands accumulated. The high diversity of Upper Maastrichtian bivalves of the Crimea confirms the shallow, probably littoral, relatively warm environments, which were formed under the Tethys influence (Dhondt, 1999). Eastern Crimea was occupied by a deep-water bathyal basin with rhythmic marl and siltstone accumulation. A very deep Great Caucasus Trough was filled intensively by calcareous and clastic fan sediments.

The Pre-Caucasus and the southern part of the Turanian Platform were covered by a relatively shallow marine basin. The western margin of the Peri-Caspian Depression in the Volga River area had a coastal belt of shallow clastic sediments (close to Penza, for example) and a more or less wide belt of clay and marl sedimentation, sometimes with abundant siliceous organisms. Several belts of carbonate and clastic sediments are also present at the eastern margin of the Peri-Caspian Depression close to the Mugodzhary Mountains. In some areas of the Mugodzhary the Palaeozoic basement is directly overlaid by Upper Maastrichtian marls. Straits which connected the RP and the Western Siberian basins continued to be active during the Late Maastrichtian. Foraminiferal faunas of the Volga River, the Peri-Caspian Depression and even in the Crimea demonstrate immigration of some characteristic Boreal species in the Late Maastrichtian. It reflects a wide faunal exchange of the basins at this time.

The Late Maastrichtian was a regressive time in the Mangyshlak area. The shallow water basin with pure carbonate sedimentation covered the whole Turanian Platform. A deepening of the basin and warming of the conditions were recognised for the *Pseudotextularia elegans* Zone. This terminal Maastrichtian impulse coincides with the short-term elegans transgression (Wicher, 1953).

4. Discussion and conclusions

The main features in the sea/continental evolution of the North-Eastern Peri-Tethys are summarised in the Fig. 12. It could be easily seen in this picture that there were several stages in the development of palaeogeographic evolution of this area in the Cretaceous. The Early Cretaceous palaeogeography was determined mainly by the evolution of a longitudinal strait, comparable with the Western Interior Seaway in North America, which was the main regulator of the Boreal (cool)/Tethyan (warm) water mass movement. This factor stressed the palaeocommunities in the RP basin, because it was relatively shallow and could not play a 'buffer' role between Tethys and Boreal basin. As is seen from the biostratigraphic scheme (Table 1) the RP basin was affected mainly by Boreal water mass during the Neocomian with the strongest influence during Late Hauterivian. The other boreal impulse was in the Early Albian. The Late Hauterivian Boreal transgression was the strongest one and affected that also the North Caucasus shelf even reached the Crimea basin. The RP basin had a strong enough fresh water supply and in the time of semi-isolation the stenohalinic forms, such as ammonites, were eliminated. It is the cause for using the belemnite zonal scale for the latest Hauterivian–earliest Aptian interval in the RP. The Tethyan water moved northward mainly in the Aptian–Albian, but also in the Early Berriasian. However, the only region with a zonation similar to the 'Mediterranean standard' is the Crimea; the North Caucasus–Tuarkyr area shows some features, similar to the north Western Europe. This phenomenon is the reflection of the palaeoclimatic zonation over the region. It is very probable that in the Berriasian–Hauterivian several shallow straits crossed the Urals, which promoted an accelerated faunal exchange between the Boreal and RP basins (Baraboshkin, 1999a). This system was closed because of the Scythian Platform–Urals (and West Siberia basin)–Novaya Zemlia–Lomonosov Swell uplift in the latest Hauterivian–Early Aptian.

The tectonical rebuilding of the whole region was in the Albian–Cenomanian when rifting or some extension took place in the Crimea–Caucasus region (Nikishin et al., 1997, 1999). This event resulted in the closing of the RP longitudinal strait and the opening of a latitudinal sea connection with the European basins and the Tethys. It is reflected in the zonal schemes for the Upper Cretaceous: they are very similar for Western and Eastern Europe. The new longitudinal strait was opened in the Turgai area in the latest Cenomanian(?)–Turonian. It connected the Peri-Tethyan seas, Western Siberia Boreal basin and joined with the Western Interior Seaway on the other side of the Hemisphere. The Northern Hemisphere Megastrait appeared. This event was extremely important for the faunal exchange and cool/warm water mixing in the area as well as for the correlation. Two-way water exchange was determined: the Tethyan water influence was recognised for the south and the south-east parts of the Western Siberian basin, while the cold Boreal water influence (siliciclastic facies) is recognised along the northern margin of the RP basin. The later factor determines the importance of the siliceous microfauna for the region. Periodical opening of the Turgai and Middle Ural straits (Coniacian–Early Campanian) resulted in migration of some species in both directions. This Megastrait was closed in the Middle–Upper Eocene.

Unfortunately the strong tectonic rebuilding of the whole area around the K/T boundary and more recent uplift erased evidence of the configuration of the North-Eastern Peri-Tethys basins and still many questions exist.

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