Quaternary ecostratigraphy and paleogeographic reconstructions of the Caspian region based on benthic foraminifera

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Introduction

Stratigraphy and paleoenvironmental reconstructions of the Caspian Quaternary are based largely on changes in the evolutionary patterns and ecological characteristics of the mollusk *Didacna* Eichwald in coastal outcrops and drillholes (Yanina, 2005, 2013; Yanina and Svitoch, 2014 [this volume]).

In contrast, this paper is focused on ecostratigraphic and paleoenvironmental reconstructions of the Caspian Quaternary using benthic foraminifera as the main evaluation tool. The value of benthic foraminifera for these purposes is well known. They are ubiquitous in marine environments and have tremendous taxonomic diversity; therefore they have the potential for diverse biological responses to environmental changes. Their tests are readily preserved in sediments and are small and abundant compared to other larger hard-shelled taxa (such as mollusks). This makes them particularly easy to recover in statistically significant numbers (Yanko et al., 1999).

In our work, we follow the Russian divisions of the Quaternary System, which separates the Quaternary into the Eopleistocene (1.8-0.78 Ma), the Neopleistocene (0.78-0.01 Ma), and the Holocene (0.01-0.0 Ma) (Zhamoida, 2002). The boundary between the Eopleistocene and Neopleistocene coincides with the Matuyama-Brunhes reversal [MBR], which is readily traced in both the BS and CS regions at the bottom of the Lower Chaudian and Gurian horizons, respectively.

The first information on Caspian foraminifera was published by Ehrenberg (1873), who identified 23 species in the surface sediments of 132 stations located at water depths of 6-836 m. Most of the species were found in areas above 25 m water depth; with increasing depth, their number decreased to 1-2 species. At least two species *(Rotalia globulosa* Ehrenberg and *Textularia globulosa* Ehrenberg) were recognized as reworked from the Cretaceous. About one hundred years later, Bening (1937) described 13 benthic species. Klenova (1956) found three recent species and plenty of reworked Cretaceous foraminifera. None of the abovementioned studies provided data on the quantitative distribution of foraminifera except for Klenova (1956), who mentioned that 75% of the foraminifcral assemblages consist of *Rotalia beccarrii* (Linne). The most complete data set on recent foraminifera of the Caspian Sea was provided by Mayer (1980). She described 18 species, two of which *(Hemisphaerammina* sp. and *Saccammina* sp.) were given in open nomenclature, two others—*Miliamina fusca* (Brady) and *Trichohyalus aguajoi* (Bermudez)—are well known from the literature, and the rest were described by Mayer for the first time. There are some recent publications on modem foraminifera of the Caspian Sea (Ghane et al., 2014) and very few (Svitoch et al., 1992) on those from Quaternary sediments of the Caspian region.

Physical environment of the Caspian Sea

The Caspian Sea is a lake without outlets surrounded by five countries: Azerbaijan, Iran, Turkmenistan, Kazakhstan, and Russia. The length of its coastline is 5580 km. Its sea level is lower than msl and fluctuates depending on the water balance: it rises if the balance is positive and declines if it is negative. The area of the Caspian Sea can be divided into three approximately equal parts: Northern, Middle, and

Southern (Aladin and Plotnikov, 2004). The Northern Caspian is the shallowest part of the basin. It comprises 29% of the entire sea area, although its volume makes up less than 1%. The area of the Northern Caspian varies from 92,750 up to 126,596 km^2, and its average volume is about 900 km^3. The depth does not exceed 10 m (average = 6 m), about 20% of the area has depths less than 1 m (Zonn, 2000). The Middle Caspian comprises 36% of the entire area with a volume of about 35% of the sea. Its area varies from 133,560 to 151,626 km^2, and its average volume is about 26,400 km^3. The average depth is about 175 m, and the greatest is 790 m (Zonn, 2000). The Southern Caspian has the largest volume, which comes to about 64% of the total volume, and its area amounts to 35% of the total area of the sea. Its area ranges between 144,690 and 151,018 km^2, and the average volume is 48,300 km^3. It is the deepest part of the basin, with maximum depth reaching 1025 m. The average depth is 300 m (Zonn, 2000).

There is one more distinguished part of the basin: a shallow (<10 m) Kara-Bogaz-Gol gulf that connects with the Middle Caspian by a narrow strait. Its area comprises 3% of the total area of the sea and is about 15,000 km^2. Being lower than the level of the sea by approximately 3-4 m, the gulf constantly “drinks” the water from the Caspian Sea, and this water, in turn, quickly evaporates.

The water balance of the Caspian is mainly determined by river runoff and rainfall (its incoming part), evaporation and water outflow into Kara-Bogaz-Gol (its outgoing part). The ground water runoff into the Caspian Sea is insignificant and therefore is frequently disregarded as an incoming component of the water balance. The most important part of the incoming water balance is the Volga runoff that makes up almost 80% of the total riverine inflow.

The major abiotic parameter of the Caspian Sea is salinity (avg 12.85 psu). Therefore, the basin is considered to be a brackish one. The lowest salinity is observed in the Northern Caspian (avg 5-10 psu) and even less in certain areas adjacent to the deltas of the rivers Volga, Ural, and Terek (2-4 psu). The salinity of the Middle Caspian is 12.7 psu. Because the eastern coast of the Middle Caspian has no river runoff, the amount of rainfall is very low, and the evaporation is high, water salinity in calm weather of the surface coastal waters can reach 13.0-13.2 psu. The salinity of the Southern Caspian is 13 psu. This salinity is lower in areas adjacent to the deltas of the rivers Kura and Sefidrud, and also in the mouth of the river Atrek. The highest salinity is observed in the Kara-Bogaz-Gol gulf. This gulf is a huge evaporator of the Caspian, and its water is brine: 300-350 psu and even higher. Based upon salinity, the Caspian waters can be subdivided into an oligo-mesohaline area in the Northern Caspian, a meso-polyhaline area in the Middle and Southern Caspian, and a hyperhaline area in the Kara-Bogaz-Gol gulf. The average salinity of the Caspian Sea is lower than that of the ocean by approximately a factor of three. However, the salinity of Caspian water is not the only aspect that differentiates it from waters of the World Ocean; it differs also in its salt composition (Aladin and Plotnikov, 2004).

Material and methods

More than 300 samples from the sea and coastal outcrops were collected and studied in a multidisciplinary effort (Yanko 1989; Svitoch et al., 1992). A map of sampled locations is provided in Yanko (1989, 1990).

Live (Rose Bengal stained) and fossil foraminifera were investigated separately as described in Yanko and Troitskaya (1987), Yanko (1989), and Yanko-Hombach (2007). Samples were soaked and washed in distilled water through a 63 pm mesh sieve. Dried samples were split with a microsplitter to avoid sample bias; whenever possible, about 300 fossil foraminifera were picked by hand (flotation in CCЦ was sometimes used) and counted for population statistics. Due to low number of tests, particularly in coastal outcrops, foraminiferal abundance per station was calculated in dry samples of 100 g weight.

All species were morphologically examined, taxonomically identified, and imaged using SEM. In our taxonomic work, we followed the suprageneric classification of the *Basics of Paleontology* (Orlov, 1959), in combination with the generic classification of Loeblich and Tappan (1988). All identified taxa were systemized as belonging to Protozoa (Class Sarcodina, Subclass Foraminifera). The collection of the Caspian foraminifera is stored in the Paleontological Museum, Odessa National University, Ukraine.

For population statistics, foraminifera are divided into dominant (<50% of a given population) and accessory species. Species that occur at ≥50% of all studied locations are considered to be widely distributed, 49–10% are frequent, 9–1% are rare, and <1% are trace. All Caspian species fall into the category of brackish fauna. Within this category, they can be divided into oligohaline (>7 psu), mesohaline (7–12 psu), polyhaline (12–14 psu), and euryhaline (>7–14 psu).

Our ecostratigraphic technique (Yanko-Hombach, 2007) is largely based on the alternation of foraminiferal assemblages and their ecological preferences in geological sections, supported by data on mollusks and occasionally C-14 assays. To delineate the main features of each assemblage and their abiotic characteristics, they are studied in different ecological settings of the Caspian Sea (Yanko, 1989, 1990).

Results and discussion

Twenty five species and subspecies of benthic foraminifera are identified in the Quaternary sediments of the Caspian Sea (Table 1).

Table 1. Quaternary foraminifera of the Caspian Sea (+ agglutinated species, * fossil only).

No	*Species*
1.	*Ammonia caspica* Stschedrina, 1975
2.	*Ammonia novoeuxinica* Yanko, 1979
3.	*Ammoscalaria* sp., in Yanko, 1989 +
4.	*Ammoscalaria verae* Mayer, 1968 +
5.	*Aubignyna eg gr. mariei* Margarel, 1970 *
6.	*Birsteiniolla macrostoma* Mayer, 1968 +
7.	*Cornuspira minuscula* (Mayer), 1968
8.	*Elphidium caspicum caspicum* Yanko, 1989
9.	*Elphidium caspicum karadenizum* Yanko, 1989 *
10.	*Elphidium eg gr. gunteri* Cole, 1931
11.	*Elphidium shochinae* Mayer, 1968
12.	*Florilus trochospiralis* Mayer, 1968
13.	*Haplophragmoides tenuicutis* (Mayer), 1972 +
14.	*Haynesina eg gr. germanica* Ehrenberg 1840 *
15.	*Hemisphaerammina* sp. +
16.	*Jadammina polystoma caspica* Mayer, 1968
17.	*Mayerella brotzkajae* (Mayer), 1968
18.	*Mayerella ex gr. brotzkajae* (Mayer), 1968
19.	*Miliammina fusca* (Brady) +
20.	*Miliolinella risilla* Mayer, 1972
21.	*Ovammina leptoderma* Mayer +
22.	*Porosononion martkobi tschaudicus* Yanko, 1989 *
23.	*Psammosphaera* sp., in Yanko, 1989 +*
24.	*Saccammina* sp. +
25.	*Spiroplectinata perexilis* (Mayer), 1968 *
26.	*Trichochyalus aguajoi* (Bermudez), 1935

Geographically, foraminifera form 17 assemblages (Table 2). The species distribution is 5 times poorer compared to the Black Sea (Yanko-Hombach, 2007) and 20 times poorer compared to the Mediterranean Sea (Cimerman and Langer, 1991).

Table 1. Live foraminiferal assemblages of the Caspian Sea (from Yanko-Hombach, 2007, Table 2).

Part of the Caspian Sea	Connection with open basin	River discharge	Area	Depth (m)	Salinity (psu)	Number of stations	Number of species	Dominant species, max %	Accessories species	Assemblage index
Northern	Free	Very strong	Volga River delta	>3	0.1-7.5 (*avg* 2.3)	10	3	*Ammonia caspica*, 96	*Ma. brotzkajae* *M. fusca*	Vo
		Strong	Northeastern inner shelf	>17	7-9	11	9	*A. caspica*, 73 *Am. verae*, 17	*Ma. brotzkajae*	NC-1
		Weak	Northwestern inner shelf	>22	9-12	11	9	*A. caspica*, 66 *Am. verae*, 19	*E. caspicum caspicum* *M. fusca*	NC-2
Central	Free	Strong	Western inner shelf	>35	11-12.5	11	11	*Am. verae*, 31 *A. caspica*, 23	*C. minuscula*	CC-1
		Weak	Western outer shelf	36-70	12.4-12.9	11	3	*A. caspica*, 88	*M. fusca* *C. minuscula*	CC-2
		Absent	Eastern inner shelf	>35	12.7-13	11	14	*A. caspica*, 50	*E. caspicum caspicum*	CC-3
		Absent	Eastern outer shelf	36-70	12.7-13	11	3	*A. caspica*, 89	*M. fusca* *C. minuscula*	CC=4
		Absent	Krasnovodsky Bay	>5	14-15	11	17	*Am. verae*, 55	*S. perexilis*	Kr
	Restricted in 1968	Absent	Kara-Bogaz –Gol Bay	>2	13-14	11	13	*A. caspica*, 54 *B. macrostoma*, 28	*T. aguajoi*	KBG-1
	Absent in 1981	Absent	Kara-Bogaz –Gol Bay	>2	60-65	11	4	*T. aguajoi*, 80	*B. macrostoma*	KBG-2
	Free in 1968	Absent	Kara-Bogaz –Gol Strait	>2	12.2-13.3	11	12	*A. caspica*, 43	*Am. verae*	KBG-s
Southern	Free	Very strong	Kura delta	>10	>3	6	3	*A. caspica*, 97	*M. brotzkajae*	Kd
		Absent	Western inner shelf	>35	12.2	11	18	*E. caspicum caspicum*, 20	*E. shohinae*	SC-1
		Absent	Western outer shelf	36-70	12.8	11	3	*A. caspica*, 91	*M. fusca*	SC-2
		Weak	Turkmensky Bay	>35	12.6-13.2	11	12	*A. caspica*, 70	*E. caspicum caspicum*	Tu
		Absent	Eastern inner shelf	>35	13	11	18	*A. caspica*, 66 *E. caspicum caspicum*, 22	*E. schohinae*	SC-3

Twenty species (mostly endemic) live in the Caspian Sea today to a maximum depth of 70 m while the remaining five species are fossil (Yanko 1989, 1990).

The Eopleistocene is represented by the Apsheronian horizon, which consists of denuded limestones with nine species of foraminifera *(E. ex gr. gunteri, H. ex gr. germanica, A. ex gr. mariei, A. novoeuxinica, E. capsicum karadenizum, P. martkobi tschaudicus, M. ex gr. brotzkae, F. trochospiralis,* and *T. aguaioi).* On average, the number of specimens is >100 (occasionally up to 400). About 70% of the species are fossil (Table 1). Some of them *(E. gunteri, H. germanica,* and *A. mariei)* are described from upper Pliocene deposits of the North Atlantic (Knudsen, 1988) and Western Europe (Brodniewicz, 1972; Feyling-Hanssen et al., 1971). Other species *(E. capsicum karadenizum* and *P. martkobi tschaudicus)* are known from Pontic sediments. There are three survival species *(A. caspica, A. novoeuxinica,* and *F. trochospiralis)* that play a dominant role in foraminiferal assemblages of the modem Northern Caspian Sea, enabling us to evaluate the salinity of the Apsheronian basin as having been around 7 psu.

The lower Neopleistocene is represented by the Bakinian horizon overlying with erosional unconformity the Asheronian horizon. The Bakinian horizon has been studied in the stratotype "Gora Bakinskogo Yarusa" [the Mountain of Bakinian stage] (Svitoch et al., 1992) and outcrops "Neftyanaya Balka" and "Uzun-Dere (Maloe Kharami)." The foraminiferal assemblage includes 13 species and is characterized by a decrease in Eopleistocene relics and an appearance of Neopleistocene species (M *brotzkajae, C. minuscula,* and *M. fused).* Based on lithological properties, the Bakinian horizon is subdivided into lower and upper parts based upon early and late Bakinian foraminiferal assemblages.

The early Bakinian assemblage contains ten species of foraminifera with rather high abundance (up to 1700 specimens). It includes two Eopleistocene relics (*Haynesina ex gr. germanica* and *Aubignyna ex gr. mariei).* A dominant role is played by *A. caspica* and *P. martkobi tschaudicus* (together 80%). An accessory group consists of frequent *A. novoeuxinica, F. trochospiralis,* rare *E. capsicum karadenizum, M. brotzkajae,* and trace *M. fusca.* There is no recent analogue to the early Bakinian assemblage. The closest one is the NC-2 recent assemblage that is distributed in the Northern Caspian Sea at water depths <22 m and salinity 9-12 psu (Table 2). The late Bakinian assemblage contains ten species with decreased abundance (<200 specimens). The dominant species is *A. novoeuxinica* (96%), *E. capsicum karadenizum* is frequent. Other species are rare or trace. There are no recent analogues to this fossil assemblage. The closest one is the CC-3 recent assemblage that inhabits the central part of the Caspian Sea at water depths >35 m and salinity 12.7-13 psu (Table 2). Comparison of both assemblages enables us to conclude that during Bakinian time, salinity increased from 10 to 14 psu.

Based on mollusks (Yanina, 2005, 2012; Yanina and Svitoch, 2014 [this volume]), the Middle Neopleistocene includes the Urunzhikian and Gyurgyanian (= lower Khazarian) horizons. We did not have material from Urunzhikian outcrops, and therefore, no description of foraminifera from the Urunzhikian horizon is provided. The Gyurgyanian horizon was studied in the outcrops "Uzun-Dere," "Adzhikabul," "Atachay," "Siazanskaya Mul'da," and "Nikol'skoe" (Northern Caspian region), where the Gyurgyanian horizon is underlain by coarse terrigenous sediments, mainly gray sands and pebbles, accumulated during a regressional stage when sea level dropped to -75 m (Yanina, 2012). The thickness of the Gyurgyanian sediments varies from 1 m to 300 m (in depressions). Mollusks are similar to those from the recent Caspian Sea, while the role of Pliocene relics is insignificant (Fedorov, 1978). The same applies to foraminifera, which are represented by 5-7 species with average abundance around 60 (sometimes 200) specimens. The dominant species are *A. caspica* and *M. brotzkajae* (95-97%). An accessory group is represented by frequent *A. novoeuxinica, F. trochospiralis,* rare *P. martkobi tschaudicus, M. fusca,* and trace *E. capsicum karadenizum.* The Gyurgyanian assemblage is rather close to the NC-1 and NC-2 recent assemblages (Table 1), enabling us to estimate the salinity of the basin at around 10 psu, excluding the Northern Caspian where it did not exceed 7-8 psu.

The upper Neopleistocene is represented by the upper Khazarian (Fedorov, 1978) and Khvalynian horizons, which have been studied in the "Yenotaevka-I" and "Lenino" outcrops that contain almost similar foraminiferal assemblages at their bottom. Dominant species are A. *novoeuxinica* and *E. capsicum capsicum* (98%). Variations are present in an accessory group of species. In particular, the late Khazarian assemblage at "Yenotaevka-I" bears some traces of freshening (absence of *E. schochinae* and *A. exiguous contractus).* In general, the late Khazarian assemblage contains nine species of foraminifera (up to 100 specimens). It differs from all the other abovementioned assemblages by the disappearance of Apsheronian *P. martkobi tschaudicus* and *E. caspicum karadenizum,* and appearance of *E. caspicum caspicum* and *E. schochinae.* The late Khazarian foraminiferal assemblage bears some similarity with the recent SC-1 and CC-1 assemblages, enabling us to evaluate the salinity at around 12-13 psu.

The Khvalynian horizon was first described by Andrusov (Pravoslavlev, 1913) as sediments corresponding to the widest transgression in the Caspian. Their accumulation took place under numerous sea-level oscillations that left geomorphological evidence in the form of terraces and coastal bars at absolute elevations between -17 m and 48 m asl. Foraminifera were studied in a number of outcrops located within the lower Volgian stratoregion ("Yenotaevka," "NikoTskoe," and "Lenino") and in some other regions (outcrops "Adgicabul," "Atachay," "Siazanskaya mulda," "Chernyiy Yar," "Raygorod," "Svetlyiy Yar," and "Nizhnee Zaymische"). Foraminiferal assemblages from all these outcrops form a rather similar Kvalynian assemblage that can be divided into two sub-assemblages (early and late Khvalynian) associated with lower and upper Khvalynian sub-horizons identified with mollusks.

The lower Khvalynian sub-horizon is represented by nearshore or shallow sands, sandy clays, and rarely clays and pebbles. Its characteristic feature is the presence of lenses of chocolate-fulvous clays with thickness about 30-40 m. Total thickness of the lower Khvalynian sediments on the platform is about 10 m, sometimes 20 m. It increases up to 100 m and more in the Western Turkmenian, Kurinian, and North Dagestanian tectonic depressions (Fedorov, 1978). The coastline of the early Khvalynian basin can be traced at 40-50 m asl (Popov, 1983). The foraminiferal assemblage is quite monotonous. It includes the lowest number of species among all other Quaternary assemblages: six with abundance < 250 specimens. The dominant species are *A. novoeuxinica, M. brotzkajae,* and *F. trochospiralis.* A significant number of young generations and a high frequency of large tests indicate favorable environmental conditions for their survival. Morphologically (especially concerning the tests of *A. caspica* and *M. brotzkajae*) and quantitatively, the early Khvalynian foraminiferal assemblage is identical to the recent CK-1 assemblage indicating a strong refreshening (up to 7 psu) of the early Khvalynian basin.

The upper Khvalynian sub-horizon has a significantly narrower distribution compared to the lower Khvalynian, being restricted by isohypse 26-27 m asl (Fedorov, 1978). The foraminiferal assemblage includes dominant *A. caspica* (96%) and accessory *M. brotzkajae, E. caspicum caspicum, F. trochospiralis,* and *A. exiguous,* with an abundance of 20-30, sometimes 100 specimens. Species *A. exiguous* is widely distributed today from the Atlantic lagoons to the Caspian Sea and from Pliocene to recent. Its appearance in this foraminiferal assemblage may indicate some normalization of the salinity regime (change in the content of salts and an increase in the amount of carbonates, probably due to evaporation).

Comparison of both sub-assemblages enables us to conclude that the early Khvalynian basin was much bigger compared to the late Khvalynian one and had a much lower salinity (7-8 psu) compared to the late Khvalynian one (12-14 psu).

The youngest sediments in the Caspian region were first described by Andrusov (1900-1901) as belonging to the Caspian horizon. Bogachev (1903) called them New Caspian. Fedorov (1946) applied this term to Holocene sediments of the entire Caspian region. The Holocene foraminiferal assemblages have been studied in several cores recovered in the western Caspian Sea, where seven foraminiferal assemblages are identified (Yanko, 1989). Four of them contain elevated frequencies of meso- and polyhaline species, while three others reveal oligohaline species. The former are distributed in coarse sediments, even conglomerates, and correspond to regressive stages of the basin's development. We call them (after Fedorov, 1978) Mangyshlakian, Chelekenian, Derbenian, and Recent beds, with corresponding foraminiferal assemblages. Oligohaline species are present in fine sediments and form the lower, middle, and upper New Caspian foraminiferal assemblages that correspond to the transgressional stages of basin development. In all seven assemblages, a dominant role is played by the oligohaline *A. caspica.* However, in the New Caspian assemblage, this species is supplemented by the oligohaline *M. brotzkajae* (up to 20%), while in the Mangyshlakian, Chelekenian, Derbenian, and Recent assemblages it is supplemented by the mesohaline *E. capsicum caspicum* (up to 20%). Within the accessory group in the New Caspian assemblages, frequent species are the oligohaline *A. verae, M. fusca,* and *F. trochospiralis,* while in the Mangyshlakian, Chelekenian, Derbenian, and Recent assemblages, the polyhaline *T. aguaioi* is frequent. In general, the Mangyshlakian and Chelekenian assemblages are rather close to SC-1 (12.1-12.2 psu), while the New Caspian is close to NC-1 (7-9 psu).

In general, the Holocene assemblages differed from the Eopleistocene and Neopleistocene ones by: (1) high frequencies of agglutinated species *(S. perexilis, H. tenuicutis, O. leptoderma, B. macrostoma, Hemisphaerammina* sp., and *Saccamina* sp.), most of which are known from the modem Caspain Sea only; and (2) very high abundances of foraminifera (tens of thousands of specimens). The stratigraphic position of the Holocene is defined by the appearance of agglutinated *A. verae* and *J. polystoma dacica,* and the wide distribution of *E. schochinae,* the youngest descendant of the Pliocene species *E. gunteri.*

Thus, in the Holocene, the Caspian Sea developed through a rhythmic regime consisting of alternations in transgressive and regressive stages with corresponding salinity 7-9 psu and 12-13 psu, respectively. Our data are in a good agreement with results obtained from mollusks (Yanina, 2012).

Conclusions

1. Most foraminiferal species in the Caspian Sea are endemics. However, among them there are Atlantic, Mediterranean, and Black Sea elements.

2. The biodiversity of Caspian foraminifera is 5 times poorer compared to that in the Black Sea (Yanko-Hombach, 2007) and 20 times poorer compared to that in the Mediterranean Sea (Cimerman and Langer, 1991). This can be explained by the long isolation of the Caspian Sea from the World Ocean, its low salinity, and the specific content of salts in the basin.

3. The boundaries between major Quaternary units in the Caspian region are determined by the most substantive changes in taxonomic content and structure of foraminiferal assemblages, in particular, on the decrease (up to total disappearance) of Pliocene-Eeopleistocene relics upward within the sedimentary column. More detailed stratification is based on emigrational sequences of foraminiferal assemblages; in particular, regressive stages in basin development are characterized by increases in meso- and polyhaline foraminifera while transgressive stages are characterized by their decrease as well as increase in oligohaline and holeuryhaline species.

4. The boundary between the Eopleistpocene and early Neopleistocene in the Caspian region is determined by the first appearance of Neopleistocene species *(M. brotzkajae*, C. *minuscula,* and *M. fusca)* that occur together with numerous Eopleistocene relics *(A. ex gr. mariei* and *H. ex gr. germanica).* Their vertical distribution is limited by the lower Neopleistocene.

5. The boundary between the early and middle Neopleistocene is detennined by the decrease in Eopleistocene relics in the geological sequences.

6. The boundary between the middle and upper Neopleistocene is determined by the total disappearance of Apsheronian *P. martkobi tschaudicus* and *E. caspicum karadenizum* and the appearance of *E. caspicum caspicum* and *E. schochinae.*

7. Only a unilateral exchange of faunas occurred when the Caspian and Pontic basins were connected. The Caspian always shared its foraminifera with the Pont, but not *vice versa.*

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