Mem. Soc. Geol. It.,
44 (1990), 167-187, 8 ff., 2 tabb

STRATIGRAPHY AND PALEOGEOGRAPHY OF THE MARINE PLEISTOCENE AND HOLOCENE DEPOSITS OF THE SOUTHERN SEAS OF THE USSR

VALENTINA YANKO (*)

ABSTRACT

A stratigraphic scheme of the Pleistocene and Holocene, based on inferred migrations and on local adaptative response of the benthic foraminiferal assemblages to climatic forcing is here presented.

About 30000 samples from holes and surface sediments collected along depth transects and shore outcrops of the Black Sea, the Caspian Sea and the Sea of Azov represent the data-base for this study.

Quaternary benthic foraminifera (no planktonic form has been found ever) are represented by 165 species and subspecies from 7 families. Most of the transformations (or morphologic changes) interpreted as evolutionary changes took place in the genera *Ammonia, Mayerella, Porosononion* and *Elphidium*.

The living benthic foraminifera are distributed on the shelf in the Black Sea, and in the inner shelf only in the Caspian Sea and in the Sea of Azov. Ecologic parameters such as salinity, water depth and temperature were measured for each species and subspecies, and a tentative ecologic classification of foraminifera has been done.

The Quaternary foraminiferal assemblages are closely related to the modern ones in their paleoecologic and zoogeographic nature. This observation, which involves an evolutionary transformation of foraminifera, allows to subdivide stratigraphically the sections considered, and allows to interpret the Quaternary deposits of the Southern Seas of the USSR in term of biofacies and paleogeography.

KEY WORDS: *benthic foraminifera, Quaternary, stratigraphy, biofacies, paleogeographic analyses.*

RIASSUNTO

In questo lavoro viene presentato uno schema stratigrafico del Pleistocene e dell'Olocene, basato sulle probabili migrazioni e sulla risposta adattativa dei foraminiferi bentonici.

Sono stati studiati circa 30000 campioni provenienti da pozzi ed affioramenti litorali del Mar Nero, Mar Caspio e Mare di Azov.

I foraminiferi bentonici del Quaternario (non sono mai state ritrovate faune planctoniche) sono rappresentati da 165 specie e sottospecie appartenenti a 7 famiglie. Molte trasformazioni (o variazioni morfologiche) interpretate come variazioni evolutive caratterizzano i generi *Ammonia, Mayerella, Porosononion, Elphidium*.

Le specie bentoniche viventi sono distribuite sulla piattaforma nel Mare Nero e nella piattaforma interna solo nel Mar Caspio e nel Mare di Azov. I parametri ecologici, come ad esempio la salinità, la profondità, la temperatura, sono state misurate per ogni specie e sottospecie. È stata quindi effettuata tentativamente una classificazione ecologica basata su queste forme.

Le associazioni a foraminiferi bentonici del Quaternario sono strettamente legate a quelle attuali in base alla loro natura paleontologica e zoogeografica.

Questa assunzione che implica una variazione evolutiva nei foraminiferi, permette di suddividere stratigraficamente le sezioni considerate, e permette di interpretare i depositi Quaternari dei Mari Meridionali dell'Unione Sovietica in termini di biofacies e paleogeografia.

INTRODUCTION

The Black Sea is a very interesting semi-isolated basin and its geologic history is connected closely with the history of the Mediterranean and the Caspian Seas. There were transgressions in periods of global warming and regressions in periods of global cooling. These transgressions took place due to the penetration of the Mediterranean waters. Therefore the marine incursions are much more clearly expressed in the Black Sea than in the Mediterranean Sea and in the Ocean. In the Mediterranean Sea and the Atlantic Ocean transgressions are recognizable in the deep-sea record by the warming trends shown by the fossil microfaunas and by the isotopic record (BERGGREN *et alii*, 1980).

The Quaternary history of the Black Sea is reflected in the sediments of the shelf and the coast. The first biostratigraphic scheme of the Quaternary deposits belongs to Dr. N.I. Andrussow (ANDRUSSOW, 1918, 1925, 1926). Many scientists supplemented and detailed the first scheme since then (ARCHANGELSKY &

(*) Tel-Aviv University, Department of Geophysics & Planetary Sciences, Tel-Aviv, Israel.

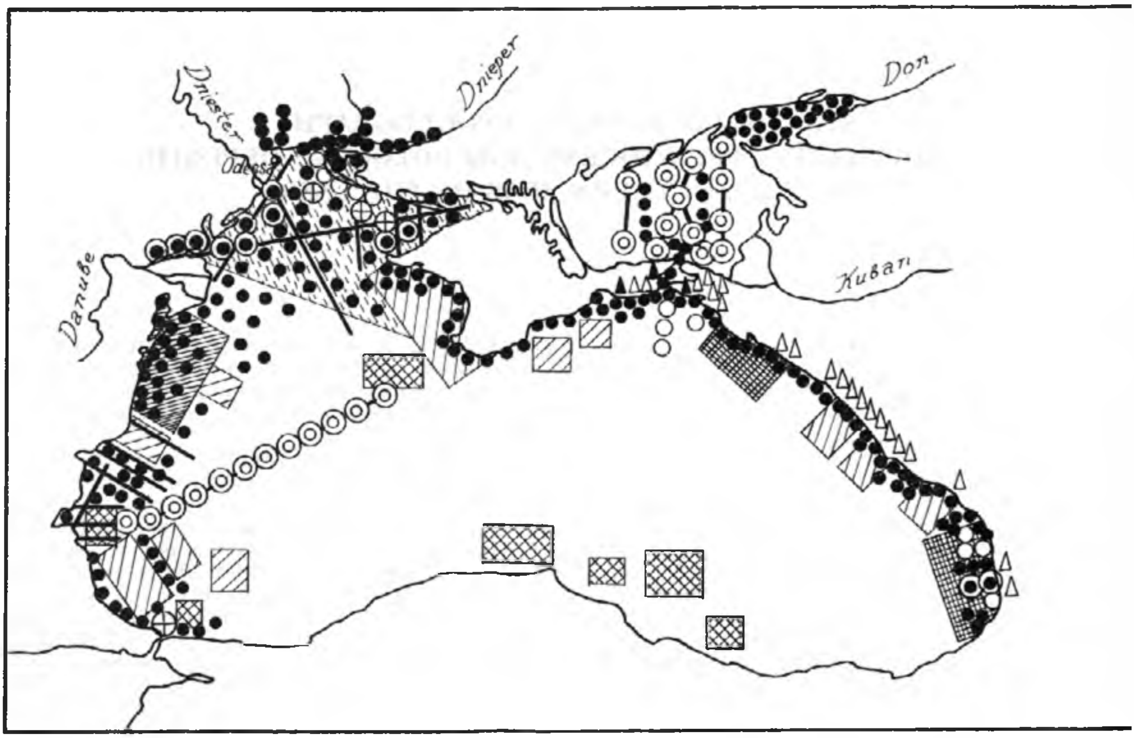

Fig. 1 - Location areas of various cores taken by different ships during 1970-1988 campaigns. Large oblique pattern Siberian Department of Sciences of the Academy of the USSR, 1985. Oblique Crossed pattern Institute of Oceanology of the Academy of Sciences of the USSR (Southern Department, Gelendzk), 1978-1979. Oblique dashed pattern = Odessa University, 1970-1984. Crossed square pattern= Southern Marine Geology Expedition (Gelendzk) 1984-1988. Fine oblique pattern = Areas of investigations performed by Roumanian scientists.

STRACHOV, 1938; FEDOROV, 1978; NEWESSKAJA, 1965; POPOV, 1983).

All these stratigraphic schemes are based on mollusca. However in the Quaternary deposits of the Southern Seas of the USSR there are others organisms as foraminifera, ostracoda and others. Their stratigraphic value has been recognized and used elsewhere (CITA *et alii*, 1974; GUDINA, 1976; FURSSENKO, 1978; AGIP, 1982). But foraminifera have not been used for stratigraphy of deposits of the Black Sea and others Southern Seas of the USSR before. GHEORGHIAN (1978) studied fossil foraminifera from the Black Sea. The results of his investigations are presented in an article which is dedicated to the micropaleontological study of deposits from DSDP Sites 379, 380, 381 (Leg 42B, the Black Sea). Foraminiferal lists includes 29 species and subspecies and their distribution into deposits. But these taxons have been used for stratigraphy in general outline. Based on the microfossils M. Gheorghian dated the deposits from these sites as the Miocene, Pliocene and Quaternary. He noted that foraminifera are absent in the Holocene, however they are abundant and diverse in the Riss, Wurm and Upper Miocene.

Our scheme is based on inferred migrations and on inferred evolutionary transformations of the microfauna. That is why all foraminiferal microfauna was investigated from taxonomic and ecologic points of view. No similar stratigraphic, ecologic and taxonomic investigations of foraminifera of this region have been done.

About 30000 samples from holes and surface sediments from depth transects and coast of the Black, and the Caspian Seas and the Sea of Azov provided the material for this study (figs. 1, 2). On each marine station water depth, salinity, temperature of the bottom waters were defined.

The Quaternary benthic foraminifera (no planktonic forms have been found) are represented by 165 species and subspecies. These

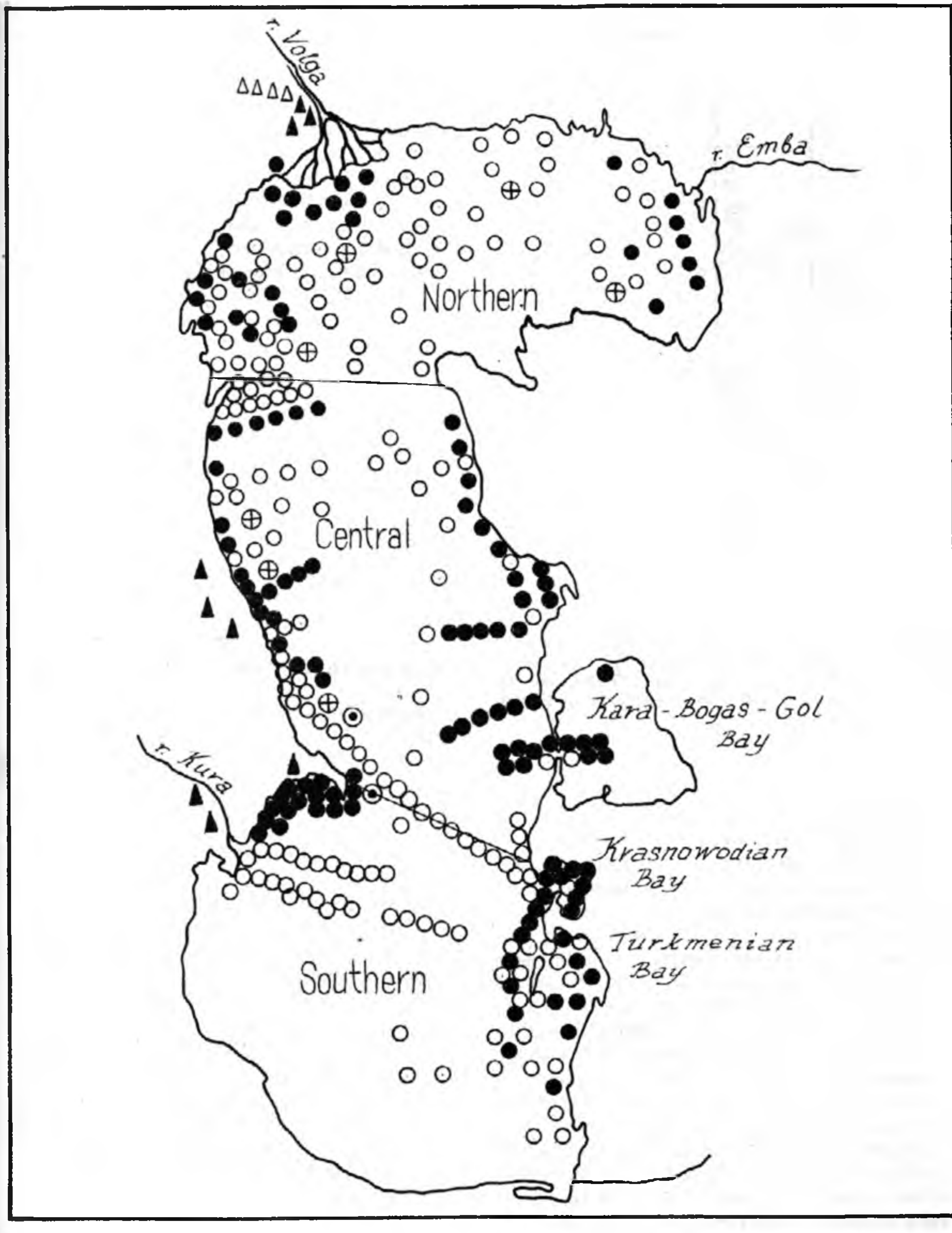

Fig. 2 - Location map. Plain line = coring transect. Open circle = Cores of Quaternary deposits about 100 m thick. Plain circle = Box-core. Open circle with point = Main core. Two open circles = Piston core. Crossed open circle = Main piston core. Open triangle = Outcrops. Plain triangles = Stratotype or key sections. See also fig. 1.

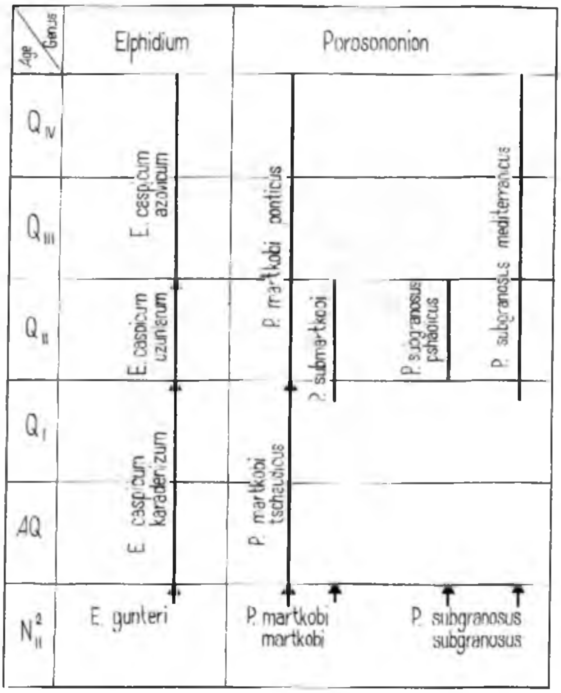

Fig. 3 - Phyletic lineages in genera Elphidium, Porosononion in the Quaternary deposits of the Black Sea. According to the subdivision adopted in the USSR, Quaternary is subdivided as follow: Q_{IV} = Holocene, Q_{III} = Upper Pleistocene, Q_{II} = Middle Pleistocene, Q_I Lower Pleistocene, AQ = Pre-Pleistocene or Eopleistocene, N_{II}^2 Upper Pliocene.

taxons belong to 7 families (Principles of Paleontology, 1959). In one of them (*Rotaliida*) rather clear evolutionary transformations have been traced and phyletic lineages could be constructed in the genera *Ammonia, Mayerella* and especially in *Elphidium* and *Porosononion*. Some parts of these phyletic lineages correspond to definite stratigraphic levels (fig. 3). For example, the Pleistocene species *Elphidium caspicum* Mayer originated from the Pliocene *E. gunteri* Cole (Mayer, 1974). In the Southern Seas of the USSR *E. caspicum* is represented by the subspecies *E. caspicum caspicum* Mayer (in the Quaternary of the Caspian Sea only), *E. caspicum karadenizum* (in the Eopleistocene and Lower Pleistocene of both the Caspian and Black Seas), *E. caspicum uzunlarum* (in the Middle Pleistocene of the Black Sea only) and *E. caspicum azovicum* (in the Upper Pleistocene and Holocene of both the Black Sea and Sea of Azov).

E. caspicum is similar to *E. gunteri* due to the type of granulation into umbilicus and structure of the interseptal bridges. But it is different by both the lesser number of chambers, interseptal bridges and coarsely perforated test (pore diameter about 4-5 μk). The difference between all subspecies of *E. caspicum* is based on sizes of the test, number of chambers, type of the tuberculation (sizes and quantity of the posses) and outline of the test. But all these forms are not different species because the main signs of *E. caspicum* as coarsely perforated test, tuberculate umbilicus and thick interseptal bridges are preserved here. The difference between the subspecies of *Porosononion martkobi* Bogdanowicz and *P. subgranosus* (Egger) is based on the size of the test, type of tuberculation into both umbilicus and septal sutures (1). All enumerated morphological signs are stable for microspheric and megalospheric generations of every subspecies and they do not depend from facies changes in synchronous deposits. They are stable both in time and space and they do not allow to consider these forms as ecophenotypes.

DISTRIBUTION OF LIVING FORAMINIFERA

Assemblages of living foraminifera were studied for definition of every species and subspecies ecology from different bionomic zones of the shelf of the Southern Seas of the USSR (depth 0-220 m, salinity 1-26‰). Water areas which were taken for this aim include deltas, open and closed lagoons (fig. 4), bays, inner and outer shelf.

The living benthic foraminifera are distributed to a maximum depth of 220 m in the Black Sea, to 70 m in the Caspian Sea. In the Sea of Azov and in the Aral Sea – which are shallow water bodies – they are present everywhere.

The quantitative distribution of species and subspecies is as follows: 104 in the Black Sea, 21 – in the Sea of Azov, 18 – in the Caspian Sea, 13 – in the Aral Sea. All of them form 50 assemblages (tab. 1) located into large ecozones: deltas, lagoons, inner and outer shelf.

(1) Descriptions, pictures, ecologic and stratigraphic data concerning the subspecies of *E. caspicum, P. martkobi* and *P. subgranosus* see Yanko, in press.

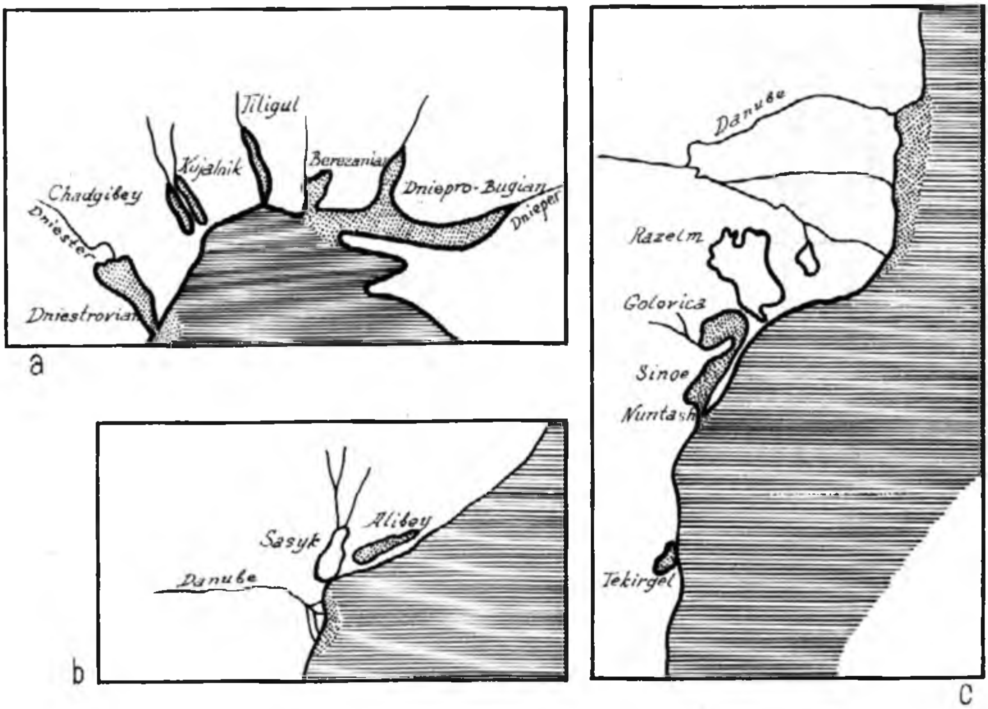

Fig. 4 - Lagoons of the North-Western shore of the Black Sea: *a*) Country between two rivers the Dnieper and the Dniester; *b*) Country between two rivers the Dniester and the Danube; *c*) Lagoons of the Rumania shore. (Legend see fig. 5).

The smallest number of species (4) is typical for deltas (1-5‰). The largest number (79) was found near of the Bosphorous (26‰). In the Black Sea the foraminiferal assemblages of the Bulgarian and Caucasian shelfs are rather similar to each other. The assemblages of the North-Western shelf are less diverse but the quantity of living foraminifera is higher there. The genus *Ammonia* which is represented by 10 species (YANKO, 1990) is dominant everywhere. Foraminiferal assemblages from deltas are characterized by high content of endemic Caspian genus *Mayerella* (YANKO & TROITSKAJA, 1987). Lagoonal foraminiferal assemblages are distinguished from shelf ones by the absence of *Lagenida*. Different species of *Ammonia* and *Porosononion* form the main body of all the Black Sea assemblages with the exception of the bays. In the bays other species appear instead of *Porosononion*. There are *Haynesina anglica* (Murray) in the Odessa Bay, *Eggerella scabra* (Williamson) in the Kalamitian Bay and different representatives of *Miliolida* in the Karkinitian Bay. The foraminiferal assemblage of the Western Shelf is distinguished from the North-Western one by the low quantity of *H. anglica, Miliolida* and also the absence of *Elphidium caspicum azovicum* Yanko. Foraminiferal assemblages of Eastern Shelf is distinguished from other ones by the presence of *Canalifera nigurensis* (Cushman). The Black Sea outer shelf foraminiferal assemblages are distinguished from those of the inner shelf by the increase of *Lagenida* and *Buliminida* especially in the western Black Sea area. It is very interesting to note that the appearance of *Acervulina, Gavelinopsis, Planorbulina, Pateoris, Pyrgo* is characteristic for the area near the Bosphorous only. The Sea of Azov foraminiferal assemblages are characterized by the increase of common species, with the Black Sea assemblages from the North to the South of the Sea of Azov and Kerchenian strait.

A main characteristic of all foraminiferal assemblages from the Caspian and Aral Seas is the absence of *Lagenida* and *Buliminida*.

High quantity of *Mayerella*, the absence of 9 species of the southern genera (*Birsteiniolla macrostoma* Mayer, *Ovammina leptoderma* Mayer, *Ammobaculites exiguus contractus*

TABLE 1

Lateral rows of living foraminifera of the Southern Seas of the USSR.

Region		Connection with sea	Influence of rivers	Salinity, ‰	Depth, m	Index of assemblage	Number of species	Dominant species, %	Typical species	Typical signs of minor group of species
	1	2	3	4	5	6	7	8	9	10
Deltas of the rivers	Danube, Dniester, Southern Bug	Through the laggons	Very strong	1	To 5	D	4	A. novoeuxinica, 76 A. tepida, 16	M. brotzkajac M. kolchidica	No
Lagoons	Dniestro-vian, Dniepro-Bugian	Constant and free	Rather strong	2-2.5	To 9	Dn	6	A. novoeuxinica, 70 A. tepida, 17 H. anglica, 12	M. brotzjkajae M. kolchidica	Presence of rare Mayerella
	Golovica, Bere-zanian	Constant and free	Insignificant	5	To 9	B	10	A. novoeuxinica, 76 A; tepida, 18 H. anglica, 4	M. fusca H. anglica	Presence of rare Mayerella. Appearance of T. aguajoi and P. subgranosus mediterranicus
	Sinoe	Constant and free	No	5	To 2	S	6	A; tepida, 81 H. anglica J. polystoma dacica 3.3	H. anglica	Apperance of Q. seminulum
	Chadgibey Tiligul	Constant trough narrow c.	Rather strong	11-12	To 19	Ch	11	A. tepida, 48 H. anglica, 41 A. novoeuxinica, 6	H. anglica	Increase of species diversity due to apperance of marine forms
	Alibey	No	No	27.4	To 2.5	A	14	H. anglica, 50 A. tepida, 40	H. anglica A. parasovica A. perlucida E. caspicum azovicum	Appearance of marine C. parkerae, D. imperspica
	Tekirgel	No	No	75	To 1	T	7	J. polystoma dacica 30 T. aguajoi, 30 A. tepida, 30	J. polystoma dacica	No
The Black Sea Bays	The Odessa Bay	Constant and free	Rather strong	3-11	To 10	Od-I	13	A. novoeuxinica, 54 H. anglica, 20 A. tepida, 14 E. caspicum azovicum, 6	E. caspicum azovicum	Increase of marine species diversity
				11-16	11-25	Od-II	33	A. tepida, 48 H. anglica, 20 P; martkobi ponticus, 12 A. parasovica, 6	A. perlucida C. poeyanum E. ponticum	Decrease of E. caspicum azovicum
	Karkinitian Bay	Constant, free	No	18.2-18.6	0-35	K	40	A. tepida, 31 Q. seminulum, 11 A. caucasica, 10	Q. laevigata Q. bicornis	Increase of Miliolida
	Kalamitian Bay	Constant, free	Insignificant	18.3	0-35	SW-I	39	A. tepida, 20 E. scabra, 15 A. caucasica, 10	M. secans A. ponticus	Increase of Miliolida and agglutinate foraminifera

Continued

Continued

Sea	Area									
The Black Sea. North-Western and Crimenian (Western) shelf area		Open shelf	No	18.3	36-70	RDW-I	38	A. compacta, 29 E. ponticum, 20 C. parkerae, 9 C. poeyanum, 12	N. matagordanus	Appearance of Lagenida
		Open shelf	No	19	71-150	DW-I	33	A. compacta, 27 P. martkobi ponticus, 12 N. matagordanus, 9 P. dzemetinica, 6 P. ex. gr. lateralis, 6 F. lucida, 6 F. solida, 5	L. vulgaris E. jatzkoi E. deplanata L. williamsoni	Increase of diversity and number of Lagenida
The Sea of Azov. The Taganrog Bay	North-Western area	Constant and free	Rather strong	4.3	To 2	Tg-I	11	A. novoeuxinica, 82 A. tepida, 9 H. anglica, 6	M. brotzkajae	All species are common with the foraminifera of the Caspian Sea
	Southern area	Constant and free	Rather strong	7-9	To 7	Tg-II	9	A. novoeuxinica, 78 A. tepida, 10 H. anglica, 6 E. caspicum azovicum, 4	H. anglica E. caspicum azovicum	Appearance of A. parasovica and disappearance of M. brotzkajae
The Sea of Azov	Centra area	Open sea	No	11-12	To 12	Az-I	17	A. parasovica, 45 A. tepida, 16 A. novoeuxinica, 10 H. anglica, 10 E. caspicum azovicum, 7	H. anglica E. caspicum azovicum	Increase of species diversity and number
	Southern area	Open sea	No	12-13	To 12	Az-II	17	A. parasovica, 39 A. tepida, 22 H. anglica, 9 E. caspicum azovicum, 6 A. perlucida, 6	H. anglica E. caspicum azovicum A. perlucida	Increase of marine species diversity and number
The Kerchenian strait	Central area	Free	No	14-15	To 10	Kr-I	17	A. parasovica, 34 A. tepida, 22 H. anglica, 10 A. perlucida, 7 E. caspicum azovicum, 6	H. anglica A. perlucida	Disapearance of many species which are common with the Caspian Sea and appearance of marine forms
	Southern area	Free	No	17.1-17.5	To 10	Kr-II	17	A. tepida, 30 A. parasovica, 28 H. anglica, 8 P. martkobi ponticus, 8 A. perlucida, 6	H. anglica P. martkobi ponticus	Disapearance of A. novoeuxinica and increase of marine species
The Black Sea. Crimenian (Eastern) shelf area		Open shelf	No		To 35	SW-II	37	A. tepida, 43 E. scabra, 13 P. martkobi ponticus, 10	C. nigarensis	Increase of quantity and number of marine species
		Open shelf	No	19-20	36-70	RDW-II	40	A. compacta, 29 C. parkerae, 16 C. poeyanum, 13	N. matagordanus	Appearance of Lagenida

Continued

Continued

The Black Sea									
Crimenian (Eastern) shelf areas	Open shelf	No	20-21	71-200	DW-II	2	A. compacta, 34 N. matagordanus, 12 P. martkobi ponticus, 9 F. lucida, 10 P. ex gr. lateralis, 4 F. solida, 5 P. dzemetinica, 4	L. vulgaris L. williamsoni E. jatzkoi	Increase of quantity and number of Lagenida
Caucasian shelf area	Open shelf	No	18-19	To 35	SW-III	42	A. compacta, 30 P. martkobi ponticus, 22 A. caucasica, 10 E. scabra, 12	A. compacta A. caucasica E. scabra	Very low content of H. anglica, E. caspicum, A. tepida
	Open shelf	No	19-20	36-70	RDW-III	41	A. compacta, 46 P. martkobi ponticus, 18 N. matagordanus, 12 C. poeyanum, 9	A. ammoniformis	Increase of F. solida and decrease of F. ponticum, C. parkerae
	Open shelf	No	20-21	71-220	DW-III	34	A. compacta, 57 F. solida, 13	E. scabra N. matagordanus, A. ammoniformis	High content and diversity of Lagenida
Bulgarian shelf area	Open shelf	No	17-19	8-35	SW-IV	38	A. tepida, 40 A. compacta, 14 A. ammoniformis, 13 P. martkobi ponticus, 10	A. caucasica C. poeyanum A. perlucida A. suchumiensis C. parkerae E. scabra E. ponticum D. imperspica	Disappearance of E. caspicum azovicum, increase of Miliolida, diversity. Low content of H. anglica
	Open shelf	No	19.0-19.6	36-70	RDW-IV	41	A. ammoniformis, 35 A. compacta, 21 C. parkerae, 12	A. tepida, P. martkobi ponticus, A. perlucida, N. matagordanus Q. vulgaris	Appearance of numerous Lagenida
	Open shelf	No	21-22	71-220	DW-IV	43	A. compacta, 30 A. ammoniformis, 15 P. ex gr. lateralis, 4 P. dzemetinica, 4 F. lucida, 4	N. matagordanus C. poeyanum	Appearance of Planorbulina, Orthomorphina, Sigmella
South-Western shelf area	Open shelf	No	21-23	71-220	DW-V	49	A. ammoniformis, 32 A. compacta, 28 P. ex gr. lateralis, F. lucida (25.14%)	P. elongata N. matagordanus, C. poeyanum, P. martcobi ponticus	Appearance of Bolivina, Brizalina, Pyrgo
	Open shelf	No	26.2	100-120	DW-IV	79	A. ammoniformis, 32 A. compacta, 28 F. fragilis, F. porecta (13%)	P. mediterranensis, B. doniczi	Increase of these genera representatives and appearance of Acervulina, Guttulina, Oolina, Gavelinopsis

Continued

Continued

The Caspian Sea	Bays	The Turkmenian Bay	Constant and free	Insignificant	12.6-13.2	To 35	Tr	17	A. caspica, 70 E. caspicum caspicum, 12.2 E. schochinae, 7	E. caspicum caspicum	Deacrease of lagoonal species T. aguajoi and increase of M. risilla
	Strait (till 1980 y)	Kara-Bo gaz-Gol	Free	No	12.2-13.26	To 2	KBG-III	12	A. caspica, 43 A. verae, 22 B. macrostoma, 18 E. schocinae	A. verae	Similar content of T. aguajoi and C. minuscula
	Middle Caspian Area	Western area	Open sea	Rather strong	10.95 12.46	To 35	MC-I	11	A. verae, 31 A. caspica, 23 B. macrostoma, 20 E. caspicum caspicum, 18	No	Disappearance of T. aguaioi Appearance of M. brotzkajae, F. trochospiralis
				Insignificant	12.44 12.86	36-70	MC-II	3	A. caspica, 88 M. fusca, 10 C. minuscula, 2	No	No
		Eastern area	Open sea	No	12.74 13.05	To 35	MC-III	14	A. caspica, 50 A. verae, 18 E. caspicum caspicum, 14	E. caspicum caspicum	Disappearance of F. trochospiralis and very low content of M. brotzkajae
			Open sea	No	12.65 12.98	36-70	MC-IV	3	A. caspica, 89 M. fusca, 9 C. minuscula, 2	No	Low quantity of M. fusca
	Southern Caspian Area	The delta of the Kura	Const. and free	Very strong	To 3	0-10	Ku	3	A. caspica, 97	M. brotzkajca	Wide distribution of M. fusca
		Western area	Open sea	No	12.1-12.2	To 35	SK-I	18	A. caspica, 72 E. caspicum caspicum, 26	E. schochinae	Low content but wide distribution of agglutinate forms. Presence species which are characterized for the southern Caspian area only
			Open sea	Insignificant	12.84	36-70	SC-II	3	A. caspica, 91 M. fusca, 8 C. minuscula, 1	No	No
		Eastern area	Open sea	No	12.93 13.1	To 35	SC-III	18	A. caspica, 65 E. caspicum caspicum, 21 E. schochinae, 8	E. schochinae	Presence of species which live in the Southern Caspian Area only
					13.1	36-70	SC-IV	3	A. caspica, 96	No	No
	The Aral Sea		No	Insignificant	9.5-11.9	4.5-10	Ar-I	12	A. verae, 58 E. schochinae, 11 B. macrostoma, 10	M. fusca	High quantity and wide distribution of M. brotzkajae
The Aral Sea			No	Insignificant	11.7-12.8	18-20	Ar-II	13	A. verae, 31.3 B. macrostoma, 1 M. brotzkajae, 15	T. aguajoi	High quantity and wide distribution of T. aguajoi

Mayer, *Jadammina polystoma caspica* Mayer, *Miliolinella risilla* (Mayer), *Trichochyalus aguajoi* (Bermudez), *Haplophragmoides tenuicutis* (Mayer), *Hemisphaerammina* sp., *Saccammina* sp. and absence of *Elphidium* in the main body of assemblages are characteristic for the North Caspian Sea area.

These signs distinguish the assemblages of the Middle and Southern areas of the Caspian Sea. The southern assemblages are distinguished from the ones of the Middle Caspian Sea area by the absence of *B. macrostoma*, the abundance of *Elphidium caspicum caspicum* Mayer, *E. schochinae* Mayer and the presence of *H. tenuicutis* in the main body of the assemblages.

The species with similar ecologic requirements were united in 8 bionomic groups: I-V in the Black Sea and the Sea of Azov, VI, VII – in the Caspian Sea, VIII – in the Aral Sea. Geographic location and salinity allow to subdivide some groups in associations.

Group I (19 species and subspecies) occupies the shallow (0-35 m) and brackish (1-19‰) biotopes of the seas. It is subdivided into 7 associations (Ia-g). For example, association Ia is characteristic for depth up to 10 m and salinity 1-5‰. It has main signs: low abundance of specimens (2-10 specimens on 100g of dry sediment) and species (only 5), mainly *Mayerella*.

Group II (7 species, 3 associations) – 0-35 m, 1-19‰;

group III (12 species, without associations) – 36-220 m, 18-26‰;

group IV (45 species and subspecies, five associations) – 71-220 m, 18-26‰;

group V (22 species and subspecies, three associations) – 0-220m, 1-26‰;

group VI (15 species and subspecies, four associations) – 0-35 m, 2-14‰;

group VII (3 species, two associations) – 0-70 m, 2-14‰;

group VIII (13 species and subspecies, without associations) – 0-20 m, 9-12‰.

All assemblages form the lateral rows (2). Each of them is an indicator of a given sedimentary environment. The zoogeographic nature of every assemblage is determined by the ratio of species from different bionomic groups into assemblages (see tab. 1).

All foraminifera of the Southern Seas of the USSR are eurihaline, eurithermal and euribathyal forms in comparison with foraminifera of the seas with normal salinity. However their distribution on the shelf of the Southern Seas of the USSR shows their different preference to salinity, temperature and depth. This allows to form an ecologic classification of foraminifera: shallow-water species (down to 35 m), relatively deep-water species (36-70 m) and deep-water species (71-220 m); oligohaline (1-5‰), holeurihaline (1-26‰), stricteurihaline (11-26‰) and polyhaline (18-26‰) species; warm-water and cold-water species (the former form the largest populations on both the North-Western shelf of the Black Sea and Northern Area of the Caspian Sea; the latter on both the South-Western shelf of the Black Sea and Southern Area of the Caspian Sea) (tab. 2) (Yanko & Troitskaja, 1987).

On the whole the assemblages of foraminifera are characterized by the increase of polyhaline, deep-water and warm-water species in the direction to the Bosphorous.

Analysis of benthic foraminifera of the Southern Seas of the USSR have defined mappable Areas which are closely associated with the water masses there (figs. 5, 6). These Areas are sufficiently large, geographically isolated, and show enough faunal differences between each other, to justify their consideration as foraminiferal zoogeographic provinces. We recognize the following provinces. In the Black Sea and the Sea of Azov: 1) North-Western Coastal Province, subdivided into *a*) delta biofacies, *b*) lagoon biofacies; 2) North-Western Inner Shelf Province, subdivided into *a*) bay biofacies, *b*) the Sea of Azov (central area) and the Kerchenian strait biofacies; 3) North-Western Outer Shelf Province, 4) South-Western Inner Shelf Province, 5) South-Western Outer Shelf Province, 6) Near Bosphorous Outer Shelf Province, 7) Eastern Inner Shelf Province, 8) Eastern Outer Shelf Province. In the Caspian Sea: 1) Northern Coastal Province (delta biofacies), 2) Northern Area (to 70 m) Province (Aral Province can be included here), 3) Central Area (to 70 m) Province, 4) Southern Area (to 70 m) Province. Provinces 1 and 2 are related to the influence of the fresh water masses of the rivers (see

(2) This name was proposed by S. Troitskiy (1979) for different groups of the organic world. It was used by T. Troitskaja and others scientists for foraminifera (Foraminifera of the Far Eastern Seas, 1979; Yanko & Troitskaja, 1987).

TABLE 2

Ecology of the foraminifera living in the Southern Seas of the USSR.

Foraminifera	Description by		
	Salinity	Depth	Temperature
1	2	3	4
1 Ammobaculites exiguus contractus*	Oligohaline (1-5‰)	SW	W
2 Ammoscalaria verae**		SW	C
3 Birsteiniolla macrostoma*		SW	W
4 Haplophragmoides tenuicutis*		SW	W
5 Hemmisphaerammina sp.*		SW?	W?
6 Jadammina polystoma caspica*		SW	W
7 Spiroplectinata perexilis**		SW	W
8 Ammonia caspica**		SW	C
9 Elphidium caspicum caspicum**		SW	W
10 schochinae**		SW	W
11 Floriulus trochospiralis**		SW	C
12 Mayerella aralica*		SW	C
13 brotzkajae***		SW	C
14 kolchidica		SW	C
15 Miliolinella rissila**		SW	W
16 Ovammina leptoderma**		SW	W
17 Saccammina sp.*		SW	W
18 Miliammina fusca**	Holeurihaline (1-26‰)	SW	C
19 Jadammina polystoma dacica		SW	C?
20 Ammonia novocuxinica		SW	C
21 parasovica		SW	C
22 tepida		SW	W
23 Cornuspira minuscula**		SW	C
24 Elphidium caspicum azovicum		SW	C
25 Haynesina anglica		SW	C
26 Porosononion subgranosus mediterranicus		SW	W
27 Quinqueloculina seminulum		SW	W
28 Rosalina catesbyana		SW?	W?
29 sp.		?	?
30 Trichochyalus aguajoi***		SW	C
31 Quinqueloculina oblonga		SW	C
32 Ammobaculites ponticus	Stricteurihaline (11-26‰)	SW	W
33 Discammina imperspica		SW	W
34 Proteonella atlantica		SW	W
35 Rotaliammina ochracea		SW	C
36 Ammonia ammoniformis		RDW	W
37 caucasica		SW	W
38 Aubignyna perlucida		RDW	W
39 suchumiensis		SW	W
40 Canalifera parkerae		RDW	C
41 Cribroelphidium poeyanum		RDW	W
42 translucens		RDW	W
43 Cornuspira planorbis		RDW	W
44 Discorbis vilardeboana		SW	C
45 Elphidium ponticum		RDW	C
46 Nonion matagordanus		RDW	W
47 pauciloculum		SW?	W?
48 Porosononion martcobi ponticus		RDW	W
49 Quinqueloculina consobrina		SW	W
50 inflata		SW	W
51 milletti		SW	W
52 Ammoscalaria sp.		DW?	W
53 Eggerella scabra		RDW	W
54 Siphonaperta sp.		DW?	W?
55 Textularia sp.		DW	W
56 Acervulina ex gr. adchaerens		DW	W
57 Ammonia compacta		RDW	W

Continued

Continued

58 Bolivina doniezi	Polyhaline (18-26‰)	DW	W
59 pseudoplicata		DW	W
60 variabilis		DW	W
61 ex gr. dilatata		DW	W
62 Bulimina aculeata		DW	W
63 elongata		DW	W
64 Brizalina ex gr. danvillensis		DW	W
65 spathulata		DW	W
66 striatula		DW	W
67 Canalifera earlandi		DW	W
68 nigarensis		DW	W
69 ex gr. verriculata		RDW	W
70 Cibicides dispars		RDW	W
71 lobatulus		DW	W
72 Cribroelphidium percursum		RDW	W
73 Discorbis bertheloti		DW	W
74 sp.		DW	W
75 Entolingulina deplanata		DW	W
76 Esosyrinx jatzkoi		DW	W
77 praelongus		DW	W
78 sp.		DW	W
79 undulosus		DW	W
80 Fissurina fabaria	Polyhaline (18-26‰)	DW	W
81 fragilis		DW	W
82 lucida		DW	W
83 porrecta		DW	W
84 solida		DW	W
85 Gavelinopsis sp.		DW	W
86 Glandulina sp.		DW	W
87 Guttulina lactea		DW	W
88 Heronallenia chasteri		DW	W
89 Lagena quadrilatera quadrilatera		DW	W
90 semistriata		DW	W
91 sp.		DW	W
92 striata		DW	W
93 vulgaris		DW	W
94 Laryngosigma williamsoni		DW	W
95 Massilina secans		DW	W
96 Miliolinella selene		DW	W
97 sp.		DW	W
98 subrotunda		DW	W
99 Oolina squamosa		DW	W
100 Orthomorphina calomorpha		DW	W
101 drammenensis		DW	W
102 filiformis		DW	W
103 Parafissurina aventricosa		DW	W
104 dzemetinica		DW	W
105 ex gr. lateralis		DW	W
106 Patcoris dilatatus		DW	W
107 Pyrgo elongata	Polyhaline (18-26‰)	DW	W
108 fisheri		DW	W
109 Planorbulina mediterranensis		DW	W
110 Quinqueloculina bicornis		SW	W
111 curvula		DW	W
112 laevigata		RDW	W
113 lamarkiana		DW	W
114 lata		SW	W
115 vulgaris		DW	W
116 sp.			
117 Sigmella distorta		DW	W
118 tenuis		DW	W
119 sp.		DW	W
120 Trifarina angulosa		DW	W
121 Elphidium ex gr. ponticum		The ecology is not known	

SW – shallow-water forms (down to 35 m); RDW – relativelly deep-water forms (36-70 m); DW – deepwater forms (71-220 m); W – warm forms; C – cold forms. * – foramifera from the Caspian Sea; ** – foramifera from the Caspian, the Black Seas and the Sea of Azov; + – foramifera from the Aral Sea.

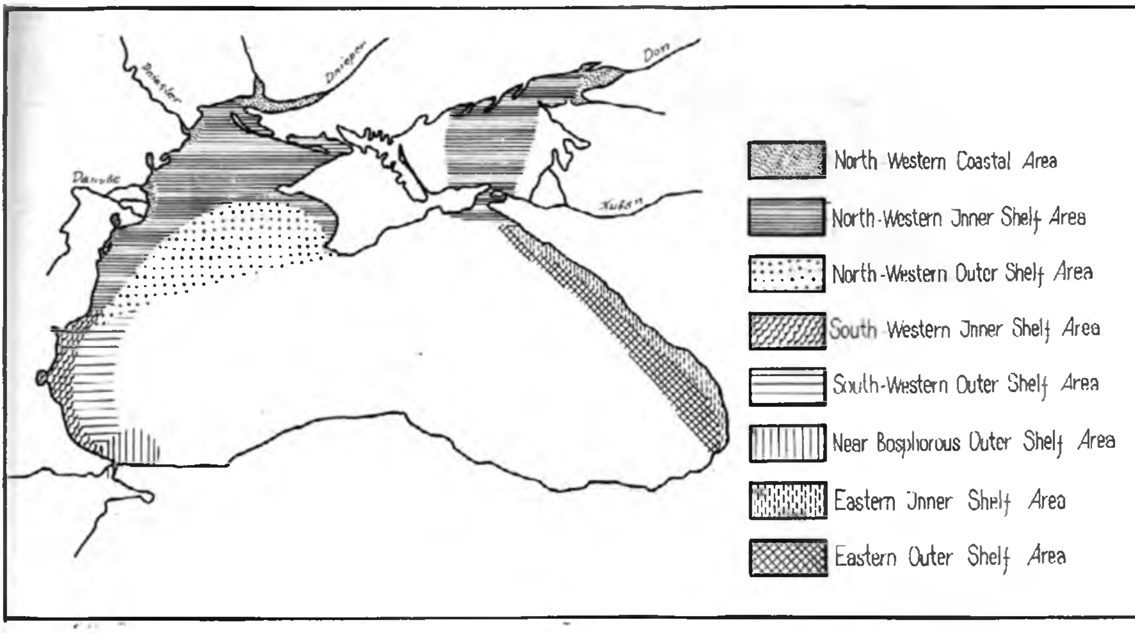

Fig. 5 - Foraminiferal Areas of the Black Sea and the Sea of Azov.

figs. 1, 2). Provinces 5 and 6 – to the influence of the Mediterranean water masses.

All species from the Black Sea and Sea of Azov are boreal ones on the whole. But there are some high boreal, low boreal and north subtropical species. That is why the provinces 1 to 3 can be considered as boreal ones, with high and low boreal elements and the provinces 4 to 8 – as boreal ones, with north subtropical elements. It is impossible to recognize the nature of the Caspian foraminiferal microfauna because it is very endemic.

DISTRIBUTION OF FOSSIL FORAMINIFERA

The Quaternary assemblages are closely related to recent ones by their paleoecologic and zoogeographic nature. This allows to subdivide stratigraphically the sections and allows to interpret the Quaternary deposits of the Southern Seas of the USSR in terms of biofacies and paleogeography with the help of the lateral rows and bionomic groups.

The Black Sea is a semi-enclosed basin and climatic fluctuations influence its fauna indirectly: in Glacial periods a decrease of salinity of the basin is recorded, due to the increased fresh water input there. In late Glacial or Interglacial periods salinity increased. That is why the increase of oligohaline mollusca, foraminifera or others groups reflects a fall in temperature (NEWESSKAJA, 1965; FEDOROV, 1978; YANKO & TROITSKAJA, 1987).

The foraminifera have been studied from all Quaternary stratotypes and type-areas (YANKO, 1989 a, b; YANKO & GRAMOVA, 1990; YANKO *et alii*, 1990; BYLINSKY *et alii*, 1990).

The Quaternary is subdivided into the Eopleistocene, Pleistocene and Holocene on the base of foraminifera. Stratigraphy is based on two criteria: a) migration of foraminifera after climatic changes and b) evolutionary transformations in some species. As a result of these transformations new species and subspecies appear at definite stratigraphic levels, thus allowing to differentiate fossil assemblages from each other.

It is important to note that an analogous conclusion has been drawn by V. GUDINA (1976). She studied the Pleistocene biostratigraphy and foraminifera of the North of the USSR and some evolutionary transformations in *Elphidium* have been determined by her there.

The most abundant and diversified foraminiferal faunas are associated with transgressive

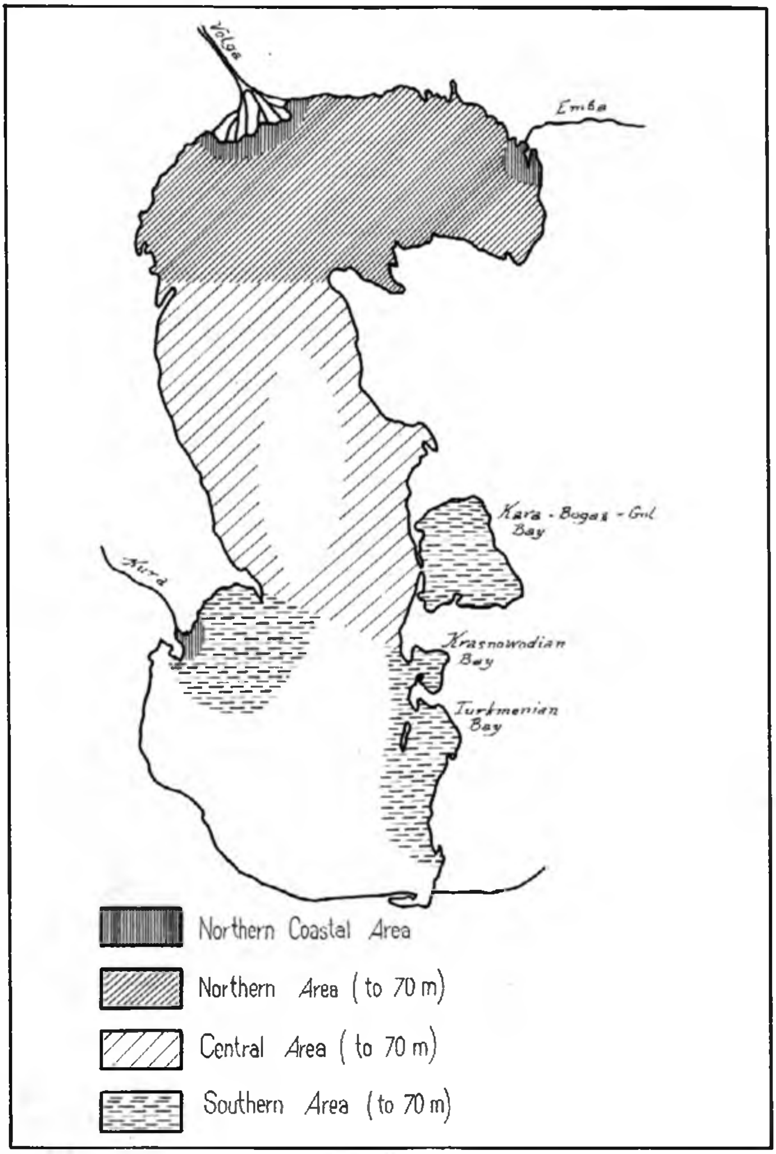

Fig. 6 - Foraminiferal Areas of the Caspian Sea.

phases corresponding to Interglacial periods. On the contrary, the regressive phases which took place in the Black Sea during Glacial periods are characterized by poor assemblages.

The boundaries between divisions of the Quaternary are based on the most important changes of foraminiferal assemblages. First of all it is the content of the Eopleistocene relicts. For example, in the Black Sea there are 36% of relicts in the Early Pleistocene, 11% – in the Middle Pleistocene and no relicts in the Late Pleistocene and Holocene. Besides, the content of the Caspian species and subspecies in the Black Sea Quaternary deposits is very important too. In the Early Pleistocene assemblages there are 54% of the Caspian forms, in the Middle Pleistocene – 6% and in the Holocene – 3%. For the Black Sea Quaternary stratigraphy the appearance of the Mediterranean species has significance too.

Similar data have been reported before on mollusca (NEWESSKAJA, 1965; FEDOROV, 1978).

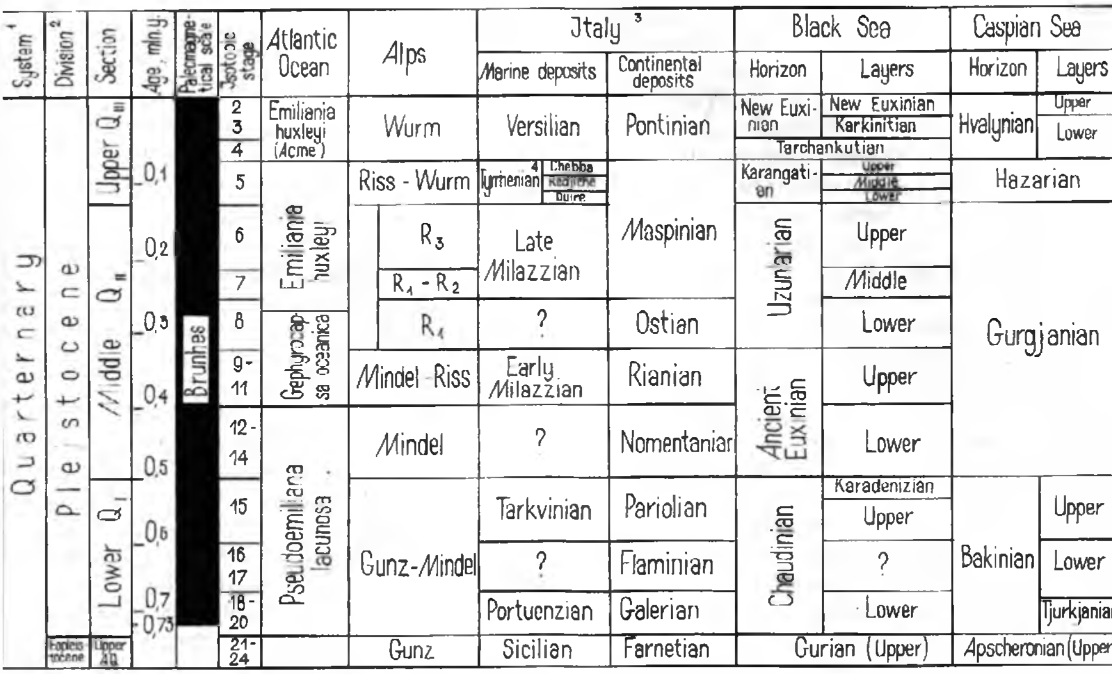

Fig. 7 - The correlation of the Pleistocene Deposits of the Southern Seas of the USSR, Italy, the Atlantic Ocean and the Alps. 1, 2) In the USSR the terms system and division are used for the Quaternary. The Quaternary system is subdivided into three divisions: the Holocene (0,0-0,01 mln.y. BP), Pleistocene (0,01-0?76 mln.y. BO) and Eopleistocene (or Pre-Pleistocene) (0,76-1,8 mln.y. BP) (Problems of geology and history of the Quaternary, 1982). 3) These data are taken from AMBROSETTI *et alii*, 1972; Problems of geology and history of the Quaternary, 1982; Problems of Upper Proterozoic and Phanerozoic Stratigraphy, 1989. 4) Subdivision of the Tyrrhenian is taken from PASKOFF & SANLAVILLE, 1983.

QUATERNARY STRATIGRAPHY

PLEISTOCENE

The poor foraminiferal assemblages fix the boundary between the Eopleistocene and the Pleistocene. In the Caspian region this boundary is determined by the first appearance of *Mayerella brotzkajae* (Mayer), *Cornuspira minuscula* (Mayer); in the Black Sea region – by the appearance of *Porosononion tschaudicus* Janko, *Ammonia novoeuxinica* Yanko and others (YANKO, 1989 a, b).

The Lower Pleistocene of the Black Sea region is represented by the Chaudinian horizon (fig. 7) exposed on the shelf and the coast. The stratotype of this horizon was determined by N. ANDRUSSOW (1989) on the South of Kerchenian peninsula (cape Chauda). These deposits were found at DSDP Site 380 (GHEORGHIAN, 1978), on the Bulgarian shelf (KUPRIN *et alii*, 1984), on the North-Western shelf (PAZJUK *et alii*, 1971), on the Caucasian shelf and continental slope (YANKO & GRAMOVA, 1990). Their thickness is 2-100 m in outcrops or around 1000 m in holes of South Georgia (KITOVANI *et alii*, 1982). In the Black Sea it is different: from 7 m (the Karkinitian Bay) to 360 m (DSDP Site 380).

Foraminiferal assemblages from the Chaudinian horizon are characterized by the highest content of the Caspian forms and the Eopleistocene relicts at the whole. But they have some differences in the lower (11 species and subspecies) and upper (9 species and subspecies) parts of this horizon. So, the assemblages from the lower deposits are characterized by higher content of the Eopleistocene relicts. There is a rather specific assemblage (19 species and subspecies) in the top of the Chaudinian horizon. It is characterized by a combination of the Caspian and high boreal and lower boreal species. This assemblage named by us as «Karadenizian» (3) is rather similar to the assemblage from the lower part of the Chaudinian horizon. Probably, it reflects the peak of the Chaudinian transgression. That is why the Karadenizian layers are not an independent biostratigraphic unit.

The Northern Caspian assemblages (NC-1) is very similar to the assemblage from the Lower Chaudinian layers of the Black Sea region. That is why we might suppose salinity in the Early Chaudinian time to be around 7‰.

At the same time the assemblage from the Upper Chaudinian layers is similar to the Northern Caspian (NC-1) and the Odessa Bay (Od-1) assemblages. It allows to suppose the highest salinity for the Late Chaudinian time to be around 8-9‰.

The assemblage from the Karadenizian layers is similar to the recent Southern Caspian (SC-1) and Bulgarian (SW-IV) assemblages. Such a combination of forms with different ecologic requirements may be accounted to an increase in salinity due to the penetration of the Mediterranean waters (YANKO *et alii*, 1984).

The Middle Pleistocene of the Black Sea region is represented by both the Ancient Euxinian and Uzunlarian horizons (ARCHANGELSKY & STRACHOV, 1938). They are recognizable in outcrops and holes (ARCHANGELSKY & STRACHOV, 1938; GORETSKY, 1955; POPOV, 1970, 1983; KATZ & SMYSLOV, 1976; KUPRIN *et alii*, 1984; Geology of the Shelf of the Ukraine, 1985).

The outcrops of the Ancient Euxinian horizon are not so complete as marine sections. The best sections with a thickness of 6-13 m were found on the North-Western shelf of the Black Sea (Geology of the Shelf of the Ukraine, 1985).

The main feature of the assemblages from the Ancient Euxinian horizon is the presence of *Porosononion subgranosus pshadicus* Yanko exclusively here. The Ancient Euxinian horizon is subdivided into the Lower and Upper Ancient Euxinian layers on foraminifera (YANKO, 1989a, b). The foraminiferal assemblages in the latter is richer (16 species and subspecies) than in the former (12 species and subspecies) due to the appearance of Southern Caspian *Trichochyalus aguajoi* (Bermudez) and polyhaline Mediterranean *Parafissurina dzemetinica* Yanko (YANKO, 1982).

The assemblage from the Lower Ancient Euxinian layers is similar to the recent Northern Caspian (NC-II) assemblage.

The assemblage from the Upper Ancient Euxinian layers is similar to both recent Northern Caspian (NC-II) and Crimean Inner Shelf (RDW-1) assemblages. It allows to suppose that at the beginning of the Ancient Euxinian time salinity was around 7‰, then it became 18‰ due to the penetration of the Mediterranean water masses.

The Uzunlarian horizon is mainly exposed in outcrops of the Kerchenian peninsula. Its identification in wells is rare. The foraminiferal assemblages were studied by us in the stratotype in the Kerchenian peninsula. The stratotype in represented by shallow deposits only. On the base of foraminifera the Uzunlarian horizon is subdivided into the Lower, Middle and Upper layers (YANKO, 1989a, b). The main diagnostic characters of these deposits are: 1) the presence of *Elphidium caspicum uzunlarum* Yanko; 2) the predominant significance of the Mediterranean forms and their combination with the Caspian forms in the lower part of the sections; 3) the increase of holeurihaline forms in the upper part of the sections.

The assemblage from the Lower Uzunlarian layers (17 species and subspecies) is similar to the recent Northern Caspian (NC-1) assemblage and at the same time it has markers of both the lagoonal (Dn,B) and Odessa Bay (Od-1) assemblages. We may suppose that salinity in Early Uzunlarian time was around 7‰.

The assemblage from the Middle Uzunlarian layers (19 species and subspecies) is similar to the recent one of the Southern area of the Sea of Azov (Az-11). Consequently, salinity was around 15-17‰ in Middle Uzunlarian time.

The assemblage from the Upper Uzunlarian layers (17 species and subspecies) is similar to the recent one of the Northern area of the Sea of Azov. That is why it is possible to suppose salinity for the Late Uzunlarian time to be around 12-13‰.

The Upper Pleistocene is subdivided into the Karangatian, Tarchancutian and New Euxinian horizon (ANDRUSSOW, 1925; ARCHANGELSKY & STRACHOV, 1938; NEWESSKAJA, 1965;

(3) Kara-Deniz, ancient name of the Black Sea.

KATZ & SMYSLOV, 1976; FEDOROV, 1978; YANKO, 1989 a,b; YANKO *et alii*, 1990).

The Karangatian horizon is widely spread in outcrops on the Kerchenian peninsula, Caucasian shore and the shelf of the Black Sea (Geology of the Shelt of the Ukraine, 1985). This horizon was found by M. GHEORGHIAN (1978) in the sites of DSDP (Leg 42B). The thickness of this horizon is very different – from 0,2m to 20m. In the DSDP Site 380 it is 16m.

Foraminifera were studied by the present author in outcrops and holes (YANKO, 1989 a, b) and, in the stratotype of this horizon in the Kerchenian peninsula (YANKO *et alii*, 1990). On the base of foraminifera this horizon is subdivided into Lower, Middle and Upper layers.

The main diagnostic indication of the Karangatian foraminiferal assemblages is the presence of the Mediterranean species which do not live in the Black Sea now. But the number of these species and its specimens is different in every assemblage. So, the assemblage from the Lower Karangatian deposits (31 species and subspecies) includes 5 Mediterranean species, from the Middle Karangatian layers (70 species and subspecies)-27 species, from the Upper Karangatian layers (39 species and subspecies)-8 species which do not live in the Black Sea now. Besides, the number of all specimens in the Middle Karangatian assemblage is some thousand. In the Lower and Upper Karangatian layers it is not more than a few hundred. Due to these faunal abundance the stratigraphic position of the Karangatian horizon is very clear. The Karangatian assemblages are the warmest and saltiest of all Pleistocene ones.

In the stratotype of the Karangatian horizon named «Eltigen» two specific foraminiferal assemblages were found. One of them is at the base of the outcrop and another one is in its top. The former includes only 10 species (around 800 specimens). It is rather similar to the recent assemblage from some lagoons (Dn,B). The latter includes 11 species (around 2000 specimens). The boreal species *Mainesina anglica* (Murray) appeares there for the first time. The first assemblage probably responds to the beginning of the Karangatian transgression. The age of the second one is not clear. Perhaps, the deposits with this assemblage correspond to an Inter Wurm transgressive phase.

Judging from the foraminiferal assemblages the Karangatian transgression was the most pronounced but it was developing in cycles. During this transgression the rise of the sea-level was irregular and interrupted by short duration lowerings. The salinity of the Karangatian basin was ranging from 0.2‰ to 30‰. The connection between the Black and Mediterranean Seas resulted in a rise of salinity whereas their isolation resulted in a salinity decrease. It is pointed out that not all the cycles of the Karangatian transgression are visible together in different outcrops or boreholes, but some of them can be traced and correlated (ARSLANOV *et alii*, 1983; YANKO *et alii*, 1990). Moreover, the cycles are visible in the outcrops or inner shelf only because they had a low amplitude (the higest level of the Karangatian transgression was no more than 20m, FEDOROV, 1978). Obviously, it is impossible to trace these cycles into the sediments of the Black Sea bed and continental slope. That is why they were not recognized in the sites of DSDP (Leg 42B) and the Karangatian horizon was not subdivided (GHEORGHIAN, 1978; Geological history..., 1980) there.

The Tarchancutian horizon was recorded in 8 boreholes on the North-Western Inner Shelf (30-35m) of the Black Sea (the Karkinitian Bay) only (NEWESSKAJA, 1965; YANKO, 1989 a, b). Its thickness is around 0,5m. The foraminiferal assemblage includes 12 species and it is very similar to the assemblages of the open lagoons (Ch,T) with salinity 11-12‰. They are characterized by the first appearance of *Haynesina anglica* (Murray) in the Pleistocene. This horizon corresponds to a transgression, possibly, of Inter Wurm age (NEWESSKAJA, 1965).

The New Euxinian horizon is represented by marine, lagoonal and continental deposits with thickness ranging from 0.1 to 20m in the Black Sea bottom only. Foraminifera were found in the first two types of sediments. On the base of foraminifera this horizon is subdivided into the Karkinitian (4) and proper New Euxinian layers. Each of them includes 11 species and subspecies. The former consists mainly of oligohaline forms and it is rather similar to the recent assemblages from the Danube delta and the Dniestrovian lagoon

(4) This name was proposed by L. NEWESSKAJA, 1965.

Division	Section	Age, ths y.	Ecozone	Horizon	Layers	Transgressive regressive cycle
Holocene	Upper	0.4	Sub Atlantic	New Chernomorian	Recent	VI
					Korsunian	V
		1.5			Nimpheyan	
		2.7			Fanagoriyan	IV
	Middle		Sub Boreal		Dzhemetinian	
		5.0			Egrissian	III
			Atlantic	Ancient Chernomorian	Kalamitian	
					Pontiyan	II
		7.8			Vityazevian	
	Lower		Boreal		Kolchidian	I
		8.0			Bugazian	
		9.1-13.0	Pre Boreal	New Euxinian	New Euxinian (Upper)	

Fig. 8 - Stratigraphic scheme of the Holocene Deposits of the Black Sea Inner Shelf (from YANKO V. & GRAMOVA L., 1990, modified).

(D,Dn). The latter includes mainly oligohaline species and it is rather similar to foraminiferal assemblages from the Berezanian lagoon (B). Obviously, at the beginning of the New Euxinian time, salinity was lesser (3-5‰) than at the end of this time (7-8‰).

HOLOCENE

The Holocene deposits are observed everywhere on the bottom of the Black Sea. Their greatest thickness is 65m on the Caucasian Shelf ant the minimum one –0,2m on the North-Western Shelf.

There is a migrational succession of foraminiferal assemblages in the majority of sections. This succession is reflected by the change from the high-salinity transgressive assemblages to the low-salinity regressive ones (YANKO & GRAMOVA, 1990). Six transgressive-regressive cycles may be recognized. They can be compared with the accepted subdivisions of the Holocene – from Pre Boreal to Sub Atlantic ecozones (fig. 8). Every cycle has a transgressive and a regressive shoulder. The transgressive shoulder is characterized: 1) by the increase in both the number of species and specimens; 2) by the reduction of the Caspian species. The regressive shoulder is characterized: 1) by the reduction of both the number of specimens and species; 2) by the increase of the oligohaline forms. The lower boundary of the Holocene is determined by the first appearance of the Mediterranean immigrants – 9580 years before present (YANKO & TROITSKAJA, 1987).

The analogous biostratigraphic, paleoecologic and paleogeographic analyses of foraminifera has been determined for the Caspian region. Here the Pleistocene deposits are divided into the Turkjanian, Bakinian, Gurgjanian, Hazarian and Hvalynian horizons. The Holocene deposits are divided into the Mangyschlakian, Lower New Caspian, Helekenian, Middle New Caspian, Derbenian and Upper New Caspian layers. All New Caspian layers are transgressive ones. The remaining ones are regressive (YANKO, 1989 a,b). All names for the Caspian stratigraphy are used by us after P. FEDOROV (1978).

CORRELATIONS

The regional stratigraphic schemes of the Black Sea and the Caspian Sea regions allow to correlate them each other and with the stratigraphic scheme of the Pleistocene of the Atlantic ocean, Alpine scale, Italy and for the Holocene with the scheme of BLYTT 1876 (figs. 7, 8). This correlation is possible: 1) on the basis of absolute age; 2) by the common succession of the climatic events and foraminiferal assemblages corresponding to these events (see pp. 2, 3); 3) by the presence of common species in the Eopleistocene, Lower

Pleistocene of the Black and Caspian Seas, the Karangatian and Tyrrhenian horizons of the Black Sea and Mediterranean Sea.

So, the Gurian and Apsheronian horizons are probably synchronous. In fact the first of them is a poor analogue of the second one. This allows to postulate a connection between the Black and Caspian Seas during the Eopleistocene and a migration of foraminifera from the Caspian Sea into the Black Sea. Both these horizons correspond to a part of the Matuyama epoch, isotopic stages 21-24, Sicilian horizon of Italy and the Gunz Glacial epoch of the Alpine scale. The Lower Chaudinian layer is regressive. It corresponds to the beginning of Early Bakinian transgression, to isotopic stages 18-20, to the Portuenzian horizon of Italy and to the beginning of the Gunz-Mindel interglacial.

The Late Chaudinian (including the Karadenizian) layers are typically transgressive. They correspond to the Upper Bakinian regressive layers, to isotopic stage 15, to the Tarquinian horizon of Italy and the most part of the Gunz-Mindel.

It is impossible to subdivide the Middle Pleistocene of the Caspian Sea on the basis of foraminifera because the changes of foraminiferal assemblages are not clear. But they are distinct in the Black Sea sections.

The Early Ancient Euxinian regressive layers probably correspond to isotopic stage 12-14 and to the Mindel.

The Late Ancient Euxinian transgressive layers correspond to isotopic stage 9-13, the Early Milazzian of Italy and the Mindel-Riss interglacial.

The Uzunlarian horizon on the whole is transgressive but its lower part corresponds to the beginning and the upper part to the end of transgression. This horizon corresponds to isotopic stages 6-8, Late Milazzian of Italy and Riss Glacial epoch.

The Karangatian transgressive horizon of the Black Sea corresponds to the Hazarian of the Caspian Sea and to the Tyrrhenian of Italy. The Lower Karangatian layers correlate with the Duira, the Middle Karangatian ones correspond to the Redjiche, the Upper Karangatian ones correlate with the Chebba. All of them correspond to isotopic stage 5 and to the Riss-Wurm interglacial.

The Tarchankutian transgressive horizon of the Black Sea corresponds to the lower part of the Lower Hvalynian layers of the Caspian Sea, probably to the lower part of the Versilian of Italy and to isotopic stage 4.

The New Euxinian regressive horizon of the Black Sea corresponds to the remaining part of the Lower Hvalynian and to the Upper Hvalynian. Also it corresponds to the upper part of the Versilian, to isotopic stages 2-3. Both the Tarchankutian and New Euxinian horizons correlate with the Wurm.

The Holocene transgression of the Southern Seas of the USSR corresponds to the Flandrian transgression of the Mediterranean Sea. Both the first and second cycles correspond to the Pre Boreal and the Boreal ecozones. The third one corresponds to the Atlantic ecozone. The fourth cycle corresponds both to the Holocene optimum and Sub Boreal ecozones. Finally the fifth and sixth cycles correspond to the Sub Atlantic ecozones.

CONCLUSIONS

The high diversity of foraminifera of the Southern Seas of the USSR disproves the former point of view that foraminiferal fauna of these seas is very poor (Principles of Paleontology, 1959). The low number of high taxonomic units is a result of both the isolation and low salinity of the Southern Seas of the USSR. A similar situation was recognized by V. Gudina (1976) for the Pleistocene foraminiferal fauna of the Northern Seas of the USSR. Consequently, it reflects the common tendency of foraminifera originating in seas with abonormal hydrology where a limited number of euryfacial families thrive (*Astrorhizida, Ammodiscida, Ataxophramiida, Miliolida, Lagenida, Buliminida*).

The representatives of three genera (*Ammonia, Porosononion, Elphidium*) form 90-95% of the entire foraminiferal assemblages, and evolutionary transformations are recorded during the Quaternary. Due to these transformations, the Quaternary stratigraphy of the Southern Seas of the USSR is based not only on climatic criteria but on biostratigraphic grounds.

On the whole the Pleistocene foraminiferal fauna is different from the Holocene one: the latter is more varied than the former. However the species not living in the Black Sea but widespread in both the Mediterranean Sea and Atlantic Ocean now, were recognized in the Upper Pleistocene only.

The recent Black Sea foraminiferal fauna essentially consist of Mediterranean immigrants. The recent foraminiferal fauna of the Sea of Azov is a poor analogue of the Black Sea fauna. The Caspian Quaternary foraminiferal fauna was formed mainly from endemics and from ancient (Pliocene?) relicts. The significance of the Caspian species in both the Black Sea and Sea of Azov assemblages is small: most of them live now in very desalinized areas (deltas, rivers mouths).

The detailed biofacial analysis of the foraminiferal assemblages allows to recognize sea-level changes, salinity, presence (absence) of the connection between the Black and Caspian Seas, the Black and Mediterranean Seas and the direction of foraminifera migration.

The highest level and salinity took place in the Karangatian and Hazarian seas, the lowest – in the Early Chaudinian, New Euxinian and Early Hvalynian ones.

A connection between the Black and Caspian seas existed from the Eopleistocene to the beginning of the Late Pleistocene, but the migration of microfauna was one-sided, namely from the Caspian Sea to the Black Sea (no Black Sea species or subspecies in the Caspian Sea during the entire Quaternary).

A connection between the Mediterranean and the Black Seas took place: 1) at the end of the Early Pleistocene, 2) twice in the Middle Pleistocene, 3) twice in the Late Pleistocene, 4) in the Holocene. The direction of foraminifera migration during every wave of migration was probably in both sides.

Manoscritto pervenuto il 21 agosto 1990.
Testo approvato per la stampa il 6 marzo 1991.
Ultime bozze restituite il 25 ottobre 1991.

REFERENCES

AMBROSETTI P., AZZAROLI A., BONNADONA F.P. & FOLLIERI M. (1972) - *A scheme of Pleistocene chronology for the Tyrrhenian side of Central Italy*. Bull. Soc. Geol. Italy, **91**.

AGIP (1982) - *Foraminiferi Padani (Terziario e Quaternario). Atlante iconografico e distribuzione stratigrafica*. II Ed. 52 plates. AGIP Mineraria SpA, Milano.

ANDRUSSOW N.I. (1889) - *About Upper Pliocene deposits of the Cape Chauda on the Kerchenian peninsula*. Proc. of society of naturalists. Geology and Mineralogy, **20**, 11-12.

ANDRUSSOW N.I. (1918) - *Geological structure of the Kerchenian strait bottom*. Preceed. Rus. Acad. Sci., **12, 6, 1**, 23-28.

ANDRUSSOW N.I. (1925) - *After Tertiary Tyrrhenian terrace in the Black Sea region*. Bull. Intern. Acad. Sci. Boheme, 165-176.

ANDRUSSOW N.I. (1926) - *Geological structure and history of the Kerchenian strait*. Bull. Mosc. Soc. Natur. Nature, Geol. Section, **34, 4, 3-4**, 294-332.

ARCHANGELSKY A.D. & STRACHOV N.M. (1938) - *Geological structure and history of the Black Sea*. Acad. Sci. USSR. Moscow, 226 p.

ARSLANOV H.A., GEY N.A., ISMAJLOV JA. A, LOKSHIN N.V., GERASIMOVA S.A. & TERTYHNY N.I. (1983) - *Age and climatic conditions of sedimentogenes on the marine terraces of the Kerchenian strait*. Leningrad Univ., **12**, 70-78.

BERGGREN W.A., BURKLE L.H., CITA M.B., COOKE H.B.S., FUNNELL B.M., GARTHER S., HAYS J.D., KENNETT J.P., OPDYKE N.D., PASTOURET L., SHACKLETON N.J. & TAKAYANAGI Y. (1980) - *Towards a Quaternary Time Scale*. Quat. Res., **13**, 277-302.

BLYTT A. (1876) - *Essay on the immigration of the norwegian flora during alternating rainy and dry periods*. Kristiania (Oslo).

BYLINSKY E.N., YANKO V.V. & MOTNENKO I.V. (1990) - *Sea level changes at the Eltigen Coastal Exposure, East Crimea*. MBSS New letter, **12**, 12-15.

CITA M.B., CIAMPO G., FERONE E., MONCHARMONT ZEI M., SCORZIELLO R. & TADDEI RUGGIERO E. (1974) - *Il Quaternario del Tirreno Abissale. Interpretazione stratigraphica e paleoclimatica del Pozzo DSDP132*. Rev. Espanola, Micropaleontol., VI, **2**, 257-326.

FEDOROV P.V. (1978) - *The Pleistocene of the Pont-Caspiy*. Moscow, Nauka, 168 pag.

Foraminifera of the Far Eastern Seas of the USSR (1979) - Novosibirsk, Nauka, 398 pag.

FURSSENKO A.B. (1978) - *Introduction in study of foraminifera*. Novosibirsk, Nauka, 215 pag.

Geological history of the Black Sea on the data of deep drilling (1980) - Moscow, Nauka, 201 pag.

Geology of the Shelf of the Ukraine. Lithology (1985) - Kiev, Naukova dumka, 189 pag.

GHEORGHIAN M. (1978) - *Micropaleontological investigations of sediments from Sites 379, 380, 381 of Leg. 42B*. Init. Repts. DSDP, **42B**, Washington (U.S. Govt. Printing Office), 783-787.

GORETSKY G.I. (1955) - *About correlation of the Uzunlarian and the Karangatian transgression*. Bull. Mosc. Soc. Natur. Nature, geol. section, **30**(2), 13-19.

GUDINA V.I. (1976) - *Foraminifera, stratigraphy and paleozoogeography of the Marine Pleistocene of the North of the USSR*. Novosibirsk, Nauka, 126 pag.

KATZ JU.I. & SMYSLOV G.A. (1976) - *New data about stratigraphy and conditions of the sedimentogenes of the Kerchenian peninsula Pleistocene deposits*. Bull. Kharkov Univ., **7**, 136, 13-19.

KITOVANI T.G., KITOVANI SH. K., IMNADZE Z.A. & TOROZOV R.I. (1982) - *New data on stratigraphy of the Chaudinian and younger deposits of Guria (Western Georgia. Quaternary system of Georgia)*. Tbilisi, 26-39.

KUPRIN P.N., SAMSONOV A.I., BABAK E.V., VARUSHENKO A.N., MONACHOV I.B. & FEDOROV P.V. (1984) - *Structure and biostratigraphy of the Quaternary deposits of the Bulgarian Shelf*. Bull. Mosc. Soc. Natur. Nature, **59**(3), 31-40.

MAYER E.M. (1974) - *Order Foraminifera in the Atlas of the Aral Sea invertebrates*. Moscow, Food Industry, 11-36.

NWESSKAJA L.A. (1965) - *Late Quaternary Bivalvia of the Black Sea, their taxonomy and ecology*. Moscow, Nauka, 391 pag.

PASKOFF R. & SANLAVILLE P. (1983) - *Les côtes dela Tunisie variations du niveau marin depuis le Tyrrhenien*. Maison de L'Orient Méditerranéen, Lyon, 190 pag.

PAZJUK L.I., PUSTYLNIK I.V., RUCHKOWSKAJA N.I., SAMSONOV A.I. & YATSKO I.JA. - *New data on stratigraphy and lithology of the Black Sea in the Eastern part of the Golitsyn structure*. J. Geol. Shore and bottom of the Black Sea and the Sea of Azov within Ukraine. Kiev, **5**, 61-73.

POPOV G.I. (1970) - *Quaternary system (Geology of the USSR)*. Moscow, Nauka, **46**, 447-492.

POPOV G.I. (1983) - *The Pleistocene of the strait of both the Black and Caspian Seas*. Moscow, Nauka, 216 pag.

Principles of Paleontology (1959). General part. Protozoa - Acad. Sci. USSR, 482.

Problems of geology and history of the Quaternary (1982) - Moscow, Nauka, 235.

Problems of Upper Proterozoic and Phanerozoic stratigraphy (1989) - Moscow, Nauka, 306 pag.

TROITSKIY S.L. (1979) - *Marine Pleistocene of the Sibirian plains: Stratigraphy*. Novosibirsk, Nauka, 292.

YANKO V.V. (1982) - *Stratigraphy of the Upper Quaternary deposits of the North-Western Shelf of the Black Sea on benthic foraminifera*. Marine Micropal., Moscow, Nauka, 126-130.

YANKO V.V. (1989a) - *Quaternary Foraminifera of the Pontian-Caspian region (their classification, ecology, biostratigraphy, hystory)*. Abstract of doctoral thesis. Moscow University, 50.

YANKO V.V. (1989b) - *Doctoral thesis*. V **1**, 308 pag., 58 fig., 33 tabl. V **2**, 426, 70 paleontol. tabl., 28 fig. Unpublished.

YANKO V.V. (in press) - *Evolution and prochorez of the benthic Foraminifera and detail biostratigraphy of the Pleistocene and Holocene deposits of the Pontian-Caspian region*. Proc. Paleontol. Sci. USSR.

YANKO V.V. (1990) - *Quaternary foraminifera of genus Ammonia of the Pontian-Caspian region*. Plaeontol. J., **1**, 18-26.

YANKO V.V. & GRAMOVA L.V. (1990) - *Stratigraphy of the Quaternary deposits of the Caucasian shelf and continental slope of the Black Sea on microfauna (foraminifera and ostracoda)*. Soviet Geology, **2**, 60-72.

YANKO V.V., CHEPALYGA A.L., BLJUM N.S. & OSKINA N.P. (1984) - *Early Quaternary marine basin of the Black Sea*. Proc **1**. All-Union school on lithology and stratigraphy of Mesozoic and Cenozoic cover of the World Ocean. Moscow, 180-183.

YANKO V.V., FROLOV V.T. & MOTNENKO I.V. (1990) - *Foraminifera and lithology of the Karangat horizon stratotype (Quaternary, Kerchenian peninsula)*. Bull. Mosc. Soc. Natur. Nature, **65**(3), 83-97.

YANKO V.V. & TROITSKAJA T.S. (1987) - *Late Quaternary foraminifera of the Black Sea*. Moscow, Nauka, 111.