УДК 551.8:551.351.2(262.5-16)

**N.V. Tyuleneva**

**CHANGES IN THE DEPOSITIONAL ENVIRONMENT OF NORTHWESTERN SHELF OF THE BLACK SEA DURING LATE PLEISTOCENE-HOLOCENE**

**Н.В. Тюлєнєва**

**ЗМІНА УМОВ ВІДКЛАДОНАКОПИЧЕННЯ НА ПІВНІЧНО-ЗАХІДНОМУ ШЕЛЬФІ ЧОРНОГО МОРЯ В ПІЗНЬОМУ ПЛЕЙСТОЦЕНІ – ГОЛОЦЕНІ**

The results of the study of the cores from 10 to 50 m water depths which were taken in the area of such paleo- river valleys as Dnieper and Dniester are presented in this research. The tendency of sedimentation environment changes during the late Pleistocene – Holocene was characterized. The transgression in the beginning of the Holocene led to the changes in the matter composition, as well as to the changes in the balance of the sediments which come into the basin.
*Keywords*: facies, Northwestern shelf of the Black Sea, the late Pleistocene – Holocene time, sediment forming processes, matter composition of the bottom deposits

В роботі наведені результати вивчення кернів відібраних на глибинах від 10 до 50 м в районах палео- річкових долин Дніпра і Дністра. Отримані дані дозволили охарактеризувати тенденцію зміни умов утворення донних відкладень в пізньому плейстоцені – голоцені. В результаті чорноморської трансгресії відбулася трансформація умов накопичення відкладів, яка, в свою чергу, призвела до зміни в балансі речовин в твердому стані, що надходять в басейн седиментації.
*Ключові слова*: фації, північно-західний шельф Чорного моря, пізній плейстоцен -голоценовий час, процеси накопичення відкладів, речовий склад донних відкладень

## INTRODUCTION

The study area is situated within the Northwestern Black Sea shelf. This part of the shelf belongs to a platform type. The surface of the shelf has rather gentle slope (1-2'), and its relief is complicated by paleo-river valley systems. The shelf area is separated from the land by coastal submarine slope, whose height is 10-15 m. In general, the slopes of the relief forms are about 20'. Further to the south from this slope, the recent surface of the shelf is divided by linear depressions which are well expressed in the relief. These depressions are the relicts of paleo-river valleys which were cut during regression periods (Fesyunov, 2000). The depths of the paleo-valleys vary from 10 to 15 m. During the Pliocene-Quaternary time, this alluvial plain was being shaped by epeirogenic and eustatic sea level variations as well as repeated reorganization of the paleo-river network (Ionin et al., 1987; Fesyunov, 1996; Suchkov et al., 2001). Exogenous processes (sedimentation, sedimentary material dispersal by currents and waves, bottom erosion and abrasion) as well as subaerial processes of continental sediment accumulation and denudation during regression periods played an important role in forming the shelf's relief. The relief was partly flattened by accumulation of marine bottom deposits (Fedoronchuk et al., 2010). All the above mentioned factors have helped create the shelf's recent relief.

Sedimentological environment reconstruction in the Northwestern Black Sea shelf during late Pleistocene-Holocene is currently debated in a series of unresolved paleogeographic questions which are widely discussed (Aksu et al., 2002; Lericolais et al., 2007; Ryan, 2007; Nicholas et al., 2011; Yanko-Hombach et al., 2011; Yanko-Hombach et al., 2013). Detailed geochemical studies in the shelf were carried out in the course of previous research (Mitropolskiy et al., 1982; Fesyunov, 2000; Suchkov and Tyuleneva, 2014) as well as in recent studies of sedimentary deposits of its continental slope (Soulet et al., 2011). However, some questions about geochemical peculiarities of some components such as silica in the bottom deposits of different facial composition and age, has not been clarified yet. The aim of this paper is to characterize the gradual change of sediments' facial composition over the course of time, on the basis of certain data about the fauna composition (mollusk fauna), and lithological and geochemical composition ($CaCO_3$ and $SiO_2$ content) of the bottom sediments in the coastal part of the Northwestern Black Sea shelf during late Pleistocene-Holocene time.

## STUDY AREA, METHODS AND RESEARCH OBJECT

The study area is situated in the Northwestern Black Sea shelf. The northern boundary of the study area is the shore line, in the south it is isobath of 55 m. The results of determination of such parameters as mollusk fauna, lithological composition and geochemistry of the sediments were used in this research. Fauna

composition and lithological determinations were carried out by the staff of Physical and Marine Geology Dept. of Odessa I.I.Mechnikov National University (ONU), Institution of Geological Sciences, NAS of Ukraine, and by SRGE Prichernomorgeologiya. Carbonate content measurements were done using value method (precision: 0.01 %); silica dioxide content was estimated by spectral analysis. The research data were obtained by marine geological survey of SRGE Prichernomorgeologiya over many years, and by Laboratory of Marine Geology and Geochemistry of ONU were also used in this paper. The investigation of facial and chemical composition of late Pleistocene-Holocene deposits on the shelf were carried out on the basis of 18 cores collected at a depth from 10 to 50 m in the paleo-river valleys of Dnieper and Dniester (Fig. 1).

## RESULTS AND THEIR ANALYSIS

The Holocene transgression had a character of ingression of marine water up along paleo-river valleys, and as a result watersheds were covered with water. The fauna composition of the sediments has since changed. That is why change of the facies from terrestrial, lacustrine to marine can be traced in depression areas. The position of the coastline in the beginning of the Holocene is shown in the map (Fig. 2). The system of large limans and bays developed on the surface of the inner shelf during that time. Coast line topography was mainly determined by subaerial plain relief features in the beginning of the Holocene (Tyuleneva, 2010).

On the basis of the data about the ratio between Caspian and Mediterranean type of mollusk fauna of late Pleistocene-Holocene sediments following stages of the evolution of the Northwestern Black Sea shelf were marked out: lacustrine (Neoeuxinian) and marine (Chernomorian). Relations of the above listed facial types of the sediments are depicted in the correlation scheme of late Pleistocene-Holocene deposits (Fig. 3).Terrestrial facies before the Holocene transgression were represented by subaerial eolian-alluvial sediments and were wide spread on the watersheds of the shelf; subaqueous alluvial facies filled paleo-river valleys. Eolian-alluvial deposits are represented by loams and loamy sands. Alluvial sediments constitute the first and the second above flood plain terraces of upper Pleistocene age and widely distributed in the Northwestern Black Sea shelf (Sibirchenko et al., 1983). Alluvial deposits are represented by grey, quartz, anisomerous sands with admixture of silt, clay, shell and plant detritus; by dense clays and layers of

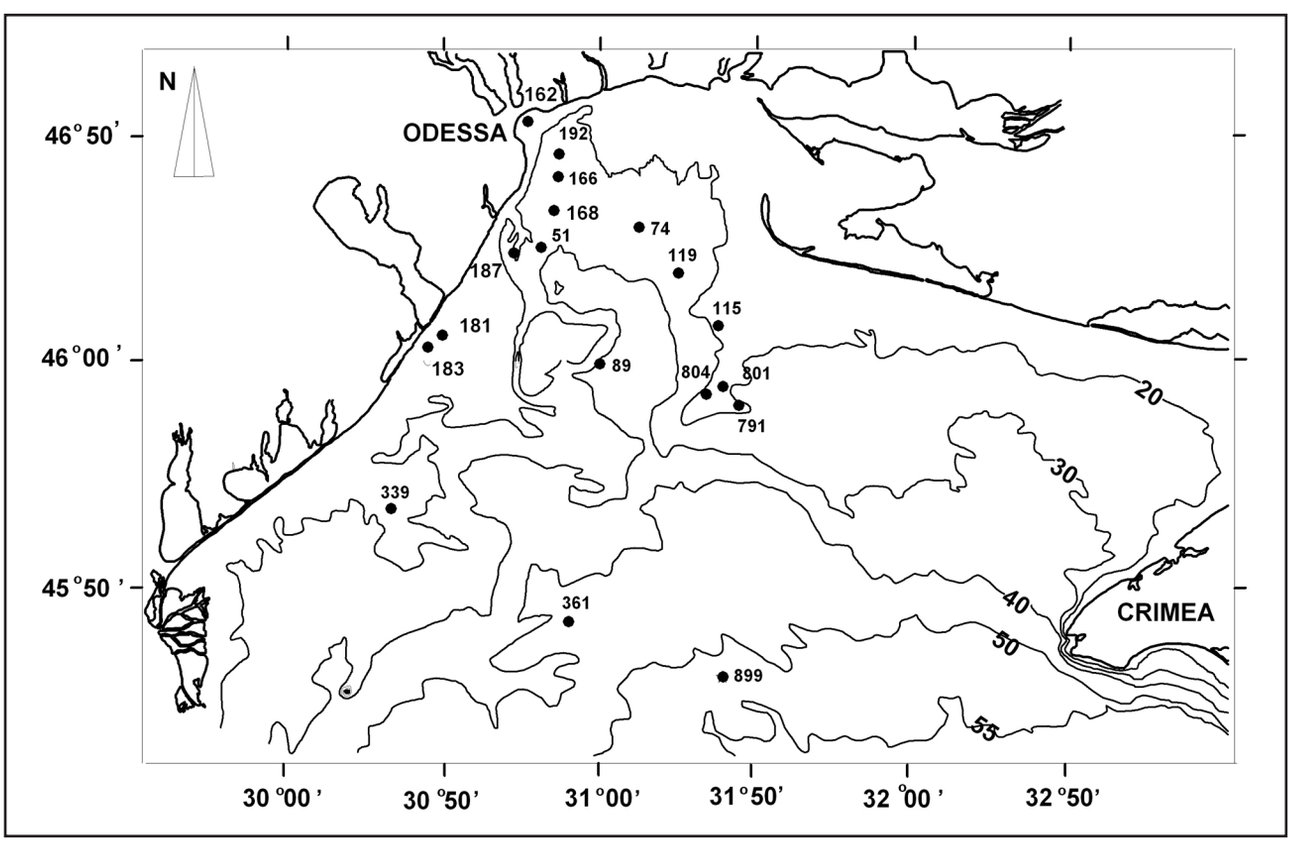


**Fig. 1.** Map of the factual material.

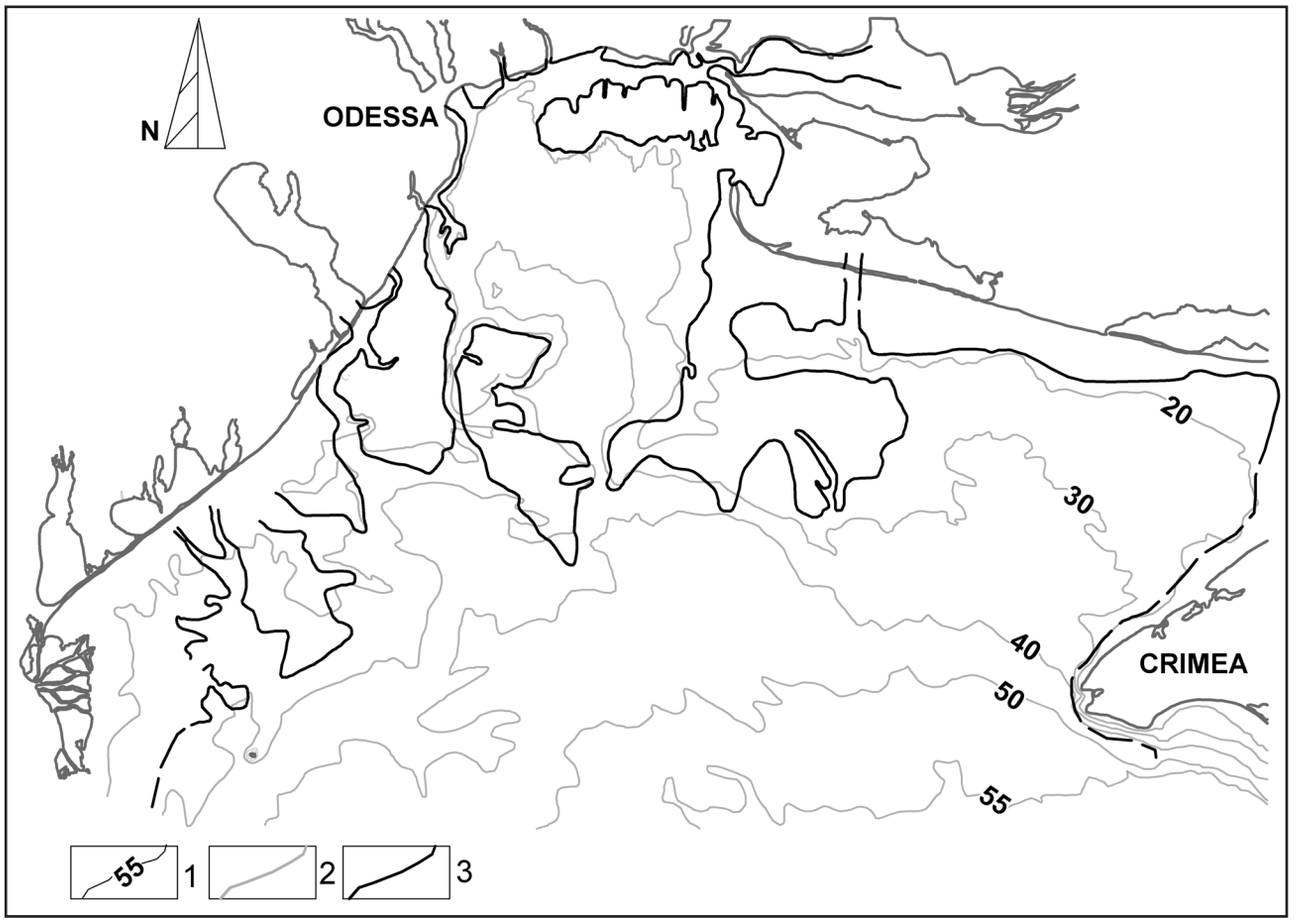


**Fig. 2.** Early Holocene coastline position: *1* – isobaths in meters; *2* – recent coastline; *3* – Early Holocene coastline.

peat. Peat layers as a rule can be encountered on top of alluvial deposits, on floodplains, but streaks of peat can also be encountered in the middle of the sedimentary sequence. Peat accumulation is related to the base level raise due to gradual transgression and as a sequence of paleo-rivers' flow deceleration. Terrestrial sediments with sharp lithological discontinuity are followed by brackish water lacustrine stage deposits at water depth of 40 m. Latter are formed by sands of greenish-grey, grey color, with quartz and admixture of shells, shell detritus and silt; by shell deposits of light-grey color with admixture of sand. Fauna is represented by brackish water Caspian species of mollusks such as *Dreissena polymorpha* (Pallas), *Dr. rostriformis* (Desh.), *Monodacna caspia* (Eichw.), *Micromelania caspia* (Eichw.), *Hypanis plicatus* (Eichw.), *Clesseniola variabilis* (Eichw.), *Viviparus viviparus* (Linne). Within shallow parts of the shelf, upwards in the sedimentary sequence, terrestrial deposits are followed by marine facies of early Holocene age (Fig. 3). The lower part of these sediments have variable lithological composition and is represented by shell deposits, clays and silty mud. The most wide spread mollusk fauna in the sediments is *Dr. polymorpha* (Pallas), *Micromelania caspia*, *Dr. rostriformis* (Desh.), *Hypanis plicatus* (Eichw.), although in the cores 183 and 899 appearance of the first Mediterranean species such as *Mytilus galloprovincialis* (Lam.) and *Cardium edule* (Linne.) can be observed. The sediments from the middle part are represented by greenish-grey mud; clayey, shell and fine sands. Mediterranean species become dominating but at the same time Caspian species can be encountered as well. The sediments from the upper part are represented by silty and clayey mud with grey hue with admixture of shell detritus and by fragments and whole shell valves; by medium and small shell fragments of olive hue; by light-grey medium sands with admixture of shell detritus. Fauna is represented by such Mediterranean mollusks as *Mytilus, Cardium exiguum, C. edule, Spisula, Rissoa sp., Chione sp.,* within the area of influence of fresh water inflow from large river systems and in limans Caspian brackish species of mollusks can be encountered.

Chemical composition variation (calcium carbonate and silica dioxide) of the bottom sediments is depicted in the graphs (Fig. 4 A, B). Carbonate content was estimated for fine and medium grained sands and mud. Late Pleistocene sediments considerably

differ from the Holocene deposits in chemical aspect. It was revealed that early Holocene sediments are characterized by following values of $CaCO_3$ in different depths within marine facies, in core 339: lower (20.28 %), middle (35.04 %) and upper part (46.76 %). The graphs in the Figure 4A depict $CaCO_3$ content in other studied cores.

The opposite tendency in variations of silica relative content was observed. As it is shown in the graphs (Fig. 4 B) the highest values have late Pleistocene alluvial deposits (from 65 to 94 %) and upwards in the sedimentary section of the Holocene deposits these values decrease to about 20-35 %.

## DISCUSSION AND CONCLUSIONS

Successive changes of facial composition was described on the basis of late Pleistocene-Holocene bottom sediments studies. Appearance of the first Mediterranean mollusks was observed in the early Holocene sediments (Fig. 3). Facial composition of the Holocene sediments makes it possible, on a local scale to allocate lower middle and upper part sediments within the marine stage. The accumulation of the lower part sediments, apparently, started after the connection with the Mediterranean Sea had been renewed, as it was supported by the presence of euryhaline species, even though their quantity is very scarce. Existing difficulties of precise time frame determination of these sediments (Tyuleneva et al., 2014) make it complicated to estimate the period of time of their accumulation. However, on the basis of existing data base of age determination (Tyuleneva et al., 2014) in general, early Holocene sediments was accumulating for about 4.3 ka years and approximate time frame of the beginning of their accumulation is from ~10.5-10 to 8.9-8.5 ka years BP (age is not calibrated, basin effect was not taken into account, that is why the precision may vary over wide ranges). One of the reasons of long duration of the distribution of Mediterranean fauna in the sediments of the lower part of marine facies could be considerable volumes of fresh water inflow into the Black Sea and in particular in its northwestern part. The transformation of fauna composition in the studied bottom sediments was determined by salinity decrement under the influence of river water runoff during all Pleistocene-Holocene history of geological development of the Black Sea basin. Overall value of inflowing fresh water into the Black Sea is about 350 $km^3$ per year (Aksu et al., 2002), and about 234 to 270 $km^3$ per year comes directly to northwestern part of the sea (Melnik, 2001). This amount of fresh water is more than 70 % from the overall value of the total riverine inflow into the Black Sea basin.

Besides fauna composition changes, the Holocene transgression determined geochemical transformation of the bottom sediments. The main source of carbonates in the coastal part is mollusk shells as it was shown in previous research (Mitropolskiy et al., 1982). The tendency of increment in carbonate content upwards in the sedimentary section from late Pleistocene to the Holocene

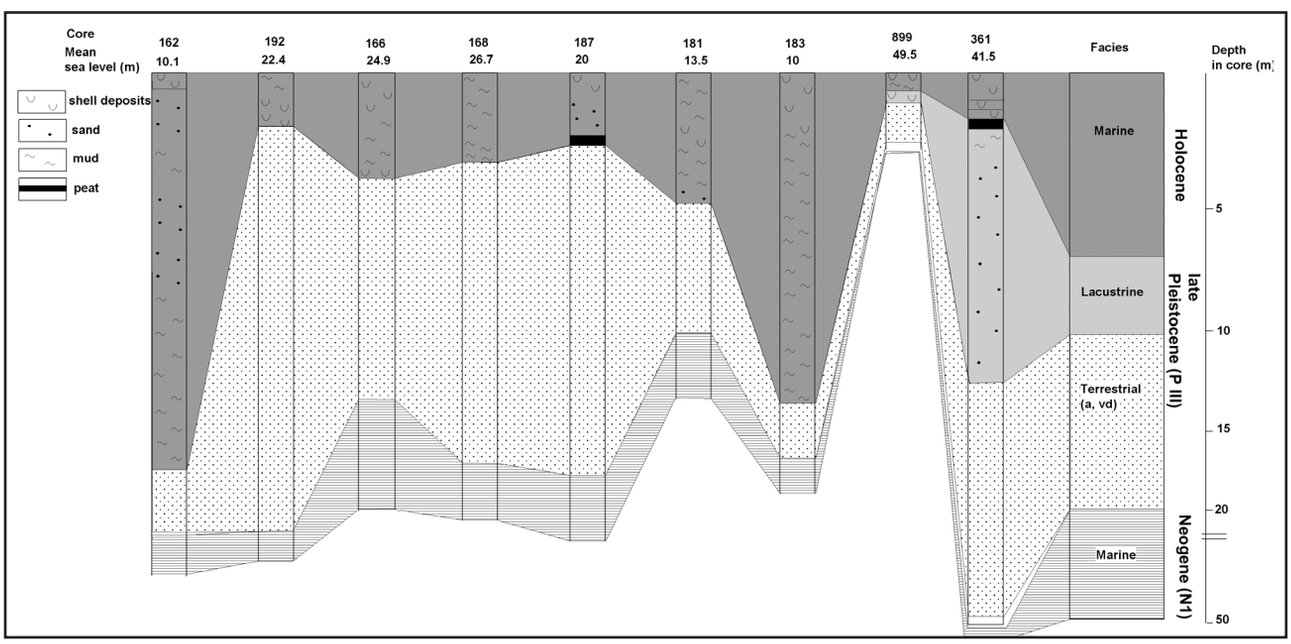


**Fig. 3.** Stratigraphy chart of late- Pleistocene and Holocene sediments.

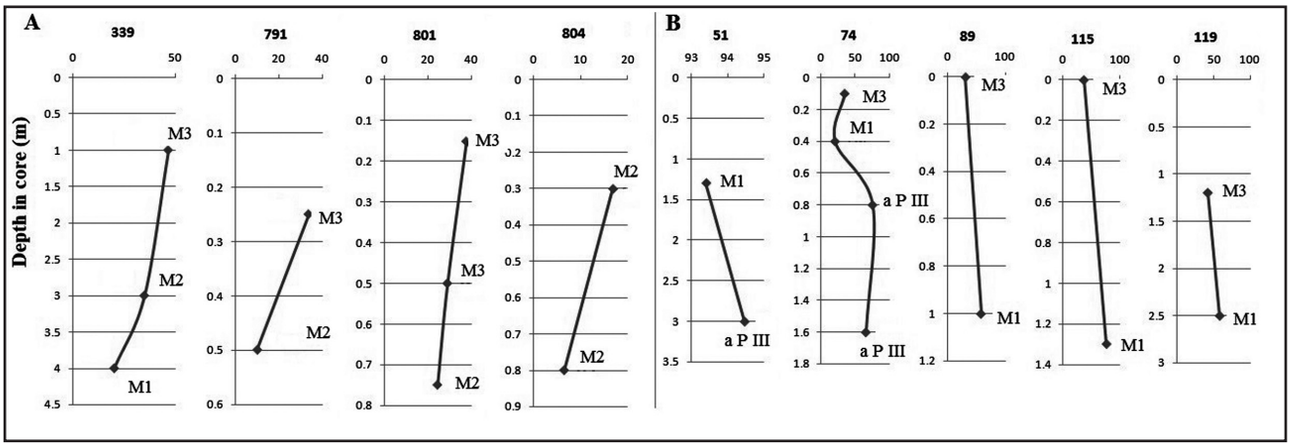


**Fig. 4.** A. Graphs of $CaCO_3$ and B. $SiO_2$ content in late- Pleistocene and Holocene sediments:
aPIII – alluvial, late Pleistocene sediments; M2 – middle, M3 – upper parts of marine stage sediments.

deposits was noted in previous studies (Fesyunov, 2000). On the one hand this pattern is connected with higher bio-productivity of Mediterranean fauna in comparison with brackish water Caspian species; on the other hand decrement of terrigenous material and less favorable climate conditions in comparison with recent, influenced carbonate material content. During late Pleistocene time, terrigenous material came straight to the shelf. This explains relatively high thicknesses of clastic material in alluvial and lake sediments, which has its reflection in high silica dioxide content. This component of the bottom sediments is the indicator of the volume of exactly terrigenous material for the basin of the Black Sea. After sea level achieved recent position the limans became the main depositional centers of the incoming land material, where the biggest part of it accumulates at the present. The data about the distribution of such lithophilous elements as zirconium and titanium which come mostly in the form of suspension together with terrigenous rivers' supply, were obtained in the course of previous research (Mitropolskiy et al., 1982, Fesyunov, 2000). The results of these studies are in agreement with the previously carried out investigations. Existing notions about silica distribution in the sedimentological sequence from late Pleistocene to the Holocene were widened. Biogenic carbonates veil the real patterns of terrigenous components distribution (Mitropolskiy et al., 1982, Fesyunov, 2000), e.g. silica in particular; however, supply of clastic material was 5-6 time higher during the lacustrine stage (Neoeuxinian time) than during the Holocene.

Obtained data allowed characterization of the tendency of bottom deposits accumulation during late Pleistocene-Holocene. The facial composition of the sediments experienced gradual changes from terrestrial to marine deposits. Observations of fresh water and mixed brackish water mollusk fauna allowed to allocate lower, middle and upper parts within the marine stage. The Holocene transgression resulted in the changes of the balance of biogenic and terrigenous components in the sediments. The results of the studies of the cores which were retrieved in a water depth from 10 to 50 m showed that from the beginning of late Pleistocene time content of carbonate material gradually increased upwards in the sedimentary sequence, in medium and fine-grained sands. The results of geochemical analysis of the sediments showed reversal tendency in silica content. Silica is the main terrigenous component. Its values decrease upwards in the sedimentary sequence from lacustrine to marine stage deposits. Thereby, the transformation of sedimentological environments was reflected in matter composition of the sediments which in its turn has changed due to alterations in the balance of terrestrial material incoming into the sedimentary basin.

REFERENCES

Ionin, A.S., Medvedev, V.S., Pavlidis, Yu.A., 1987 , Shelf, relief, sediments and their accumulation, *Mysl*, Moscow, 205 p. (In Russian).

Melnik, V.I. 2001 , «River network influence on the relief and sedimentforming processes in the Black Sea», Coastal and shelf zones ecological safety and integrated studies of the

Ионин А.С. Шельф: рельеф, осадки и их формирование / А.С. Ионин, В.С. Медведев, Ю.А. Павлидис – М.: *Мысль*. 1987, – 205 с.

Мельник В.И. Влияние речной сети суши на рельеф и осадконакопление в Черном море / В.И. Мельник // Экологическая безопасность прибрежной и шельфовой

shelf natural resources investigation, issue 4, EKOSI *Gidrofizika*, Sevastopol, pp. 112-124. (In Russian).

Mitropol'skiy, A.Yu., Bezborodov, Ye.I., Ovsyanyy, A.A., 1982, Geochemistry of the Black Sea., *Naukova dumka*, Kiev, 144 p. (In Russian).

Sibirchenko, M.G., Karpov, V.A., Ivanov, V.G., 1983 , «Technical report about bottom sediments lithological composition in the Black Sea for the purposes of geological-lithological map compilation», *Marine Geological Survey Detachment SRGE,* Odessa, 150 p. (In Russian).

Suchkov, I.A., Tyuleneva, N.V., 2014 , «Geochemistry of sediment forming processes in the Northwestern Black Sea shelf», *Herald Odessa National University,* Series of Geographical and Geological Sciences, v. 19. issue 1 (20), pp. 196-204 (in Russian)..

Suchkov, I.O., Fedoronchuk, N.O., Chepizhko, O.V., 2001, «Paleogeography and history of development of the Northwestern Prichernomor'e», *Herald Odessa National University,* Series of Geographical and Geological Sciences, Geographical and Geological Sciences v. 6, issue 9, pp. 89-96. (In Ukrainian).

Tyuleneva, N.V., 2010 , «Bottom sediments forming conditions in the Northwestern Black Sea shelf during the Bugazian time Early Holocene», *Geology and mineral resources of World Ocean*, issue 4 22, pp. 65-74. (In Russian).

Fedoronchuk, N.A., Suchkov, I.A., Tyuleneva, N.V., 2010, «Main features of recent sedimentation within Zmiinyi Island», *Collection of scientific works of the Institute of Geological Sciences NAS of Ukraine,* pp. 204-211. (In Russian).

Fesyunov, O.Ye., 1996, «Bottom marine landscapes of the Black Sea», *Priroda, issue 2*, pp. 71-76. (In Russian).

Fesyunov, O.Ye., 2000, Geoecology of the Northwestern Black Sea shelf ., Odessa, 100 p. (In Russian).

Yanko-Khombakh, V.V. Smyntyna, Ye.V., Kadurin, S.V., Larchenkov, Ye.P., Kakaranza, S.V., Kiosak, D.V., 2011 , «Black Sea level changes and adaptation strategies of prehistoric populations during the last 30 ka», *Geology and mineral resources of World Ocean, 2* , pp. 61-94. (In Russian).

Aksu, A.E., Hiscott, R.N., M.A., Mudie, P.J., Gillespie, H., T.,Yasar, D., 2002. Last glacial-Holocene paleoceanography of the Black Sea and Marmara Sea: stable isotopic, foraminiferal and coccolith evidence. *Marine Geology* 190, 119-149.

Lericolais, G., Popescu, I., Guichard, F., Popescu, S.M., 2007. A Black Sea Lowstand at 8500 Yr B.P. Indicated by a Relict Coastal Dune System at a Depth of 90 M below Sea Level. Coastline Changes: Interrelation of Climate and Geological Processes, vol. 426. *The Geological Society of America*, pp. 171-188. Special Paper.

зон и комплексное использование ресурсов шельфа. – Севастополь ЭКОСИ – *Гидрофизика*, 2001. – Вып. 4. (памяти Н.А. Панталеева) – С. 112-124.

Митропольский А. Ю. Геохимия Черного моря / А. Ю. Митропольский, А.А. Безбородов, Е.И. Овсяный – Киев : *Наукова думка*, 1982. – 144 с.

Отчет по изучению литологического состава донных отложений шельфа Черного моря с целью составления геолого-литологической карты в пределах листов L-36-XX, XXV, XXVI, XXXI, XXXII, L-35XXX. Сибирченко М.Г., Карпов В.А., Иванов В.Г. *Морская гологосъемочная, геологопоисковая партия*. – Одесса, 1983. – 150 с.

Сучков И.А. Геохимия процессов осадконакопления на северо-западном шельфе Черного моря / И.А. Сучков, Н.В. Тюленева // *Вестник Одесского национального университета*. Географические и геологические науки. – Одесса, 2014. – Т. 19. в. 1 (20), С. 196-204..

Сучков І.О. Палеогеоморфологія і історія формування північно-західного шельфу Чорного моря / І.О. Сучков, Н.О. Федорончук, О.В. Чепіжко // *Вестник Одесского национального университета.* Географические и геологические науки. – Одесса, 2001. – Т. 6, в. 9. – С. 89-96.

*Тюленева Н.В.* Условия формирования донных отложений на северо-западном шельфе Черного моря в бугазское время (ранний голоцен) / Н.В. Тюленева // *Геология и полезные ископаемые Мирового океана* – 2010. – № 4 (22). – С. 65-74.

Федорончук Н.А. Основные черты современного осадконакопления в районе острова Змеиный / Федорончук Н.А., Сучков И.А., Тюленева Н.В. // *Сборник научных трудов Института геологических наук* НАН Украины. – 2010. – Вып. 3. – С. 204-211.

Фесюнов О.Е. Донные ландшафты северо-западного шельфа Черного моря / О.Е. Фесюнов. – *Природа*. – 1996, № 2, – С. 71-76.

Фесюнов О.Е. Геоэкология северо-западного шельфа Черного моря / Фесюнов О.Е. – Одесса: *Астропринт,* – 2000. – 100 с.

Янко-Хомбах В.В. Колебания уровня Черного моря и адаптационная стратегия древнего человека за последние 30 тысяч лет / В.В. Янко-Хомбах, Е.В. Смынтына, С.В. Кадурин, Е.П. Ларченков, И.В. Мотнкнко, С.В. Какараза // *Геология и полезные ископаемые мирового океана.* – Выпуск № 2. – 2011. – С. 61-94.

Aksu, A.E., Hiscott, R.N., Kaminski, M.A., Mudie, P.J., Gillespie, H., Abrajano, T.,Yasar, D., 2002. Last glacial-Holocene paleoceanography of the Black Sea and Marmara Sea: stable isotopic, foraminiferal and coccolith evidence. *Marine Geology* 190, 119-149.

Lericolais, G., Popescu, I., Guichard, F., Popescu, S.M., 2007. A Black Sea Lowstand at 8500 Yr B.P. Indicated by a Relict Coastal Dune System at a Depth of 90 M below Sea Level. Coastline Changes: Interrelation of Climate and Geological Processes, vol. 426. *The Geological Society of America*, pp. 171-188. Special Paper.

Nicholas, W.A., Chivas, A.R., Murray-Wallace, C.V., Fink, D., 2011. Prompt transgression and gradual salinisation of the Black Sea during the early Holocene constrained by amino acid racemization and radiocarbon dating. *Quaternary Science Review* 30, 3769-3790.

Ryan, W.B.F., 2007. Status of the Black Sea flood hypothesis. In: Yanko-Hombach, V., Gilbert, A.S., Panin, N. (Eds.), The Black Sea Flood Question: Changes in Coastline, Climate and Human Settlement. *Springer,* New York, pp. 63–88.

Soulet, G., Menot, G., Garreta, V., Rostek, F., Lericolais, G., Bard, E., 2011. Black Sea «Lake» reservoir age evolution since the Last Glacial – Hydrologic and climatic implications, *Earth and Planetary Science Letters*, 308, 1-2, pp. 245 – 258.

Tyuleneva, N.V., Suchkov, I.A., Fedoronchuk N.A*.,* 2014. Changes in coastline positions during the Holocene in the shelf of the Northwestern Black Sea. *Quaternary International* 345: 77-87 doi: 10.1016/j.quaint.2013.07.041

Yanko-Hombach, V., Mudie, P.J., Kadurin, S., Larchenkov E., 2013. Holocene marine transgression in the Black Sea: New evidence from the northwestern Black Sea shelf, *Quaternary International*, http://dx.doi.org/10.1016/j.quaint.2013.07.027

Nicholas, W.A., Chivas, A.R., Murray-Wallace, C.V., Fink, D., 2011. Prompt transgression and gradual salinisation of the Black Sea during the early Holocene constrained by amino acid racemization and radiocarbon dating. *Quaternary Science Review* 30, 3769-3790.

Ryan, W.B.F., 2007. Status of the Black Sea flood hypothesis. In: Yanko-Hombach, V., Gilbert, A.S., Panin, N. (Eds.), The Black Sea Flood Question: Changes in Coastline, Climate and Human Settlement. *Springer*, New York, pp. 63–88.

Soulet, G., Menot, G., Garreta, V., Rostek, F., Lericolais, *G., Bard, E.*, 2011. Black Sea «Lake» reservoir age evolution since the Last Glacial – Hydrologic and climatic implications, *Earth and Planetary Science Letters*, 308, 1-2, pp. 245 – 258.

Tyuleneva, N.V., Suchkov, I.A., Fedoronchuk N.A., 2014. Changes in coastline positions during the Holocene in the shelf of the Northwestern Black Sea. Quaternary International 345: 77-87 doi: 10.1016/j.quaint.2013.07.041

Yanko-Hombach, V., Mudie, P.J., Kadurin, S., Larchenkov E*.,* 2013. Holocene marine transgression in the Black Sea: New evidence from the northwestern Black Sea shelf, *Quaternary International*, http://dx.doi.org/10.1016/j.quaint.2013.07.027

Manuscript resived 2 November 2014;
revision accepted 30 January 2015.

Одеський національний університет імені І.І. Мечникова,
Одеса, Україна
tyuleneva@onu.edu.ua
Рецензент: О.Ю. Митропольський