GLOBAL GEOLOGICAL PROCESSES IN THE CASPIAN-MEDITERRANEAN REGION DURING THE MIOCENE-PLEISTOCENE

Esin, N.V. [1], Esin, N.I.[2], and Yanko-Hombach, V.[3,4]

[1, 2] Shirshov Institute of Oceanology, Russian Academy of Sciences, 1-g Prostornaya Str., Gelendzhik, Krasnodar region, Russia 353467
[1] ovos_oos@mail.ru
[2] esinnik@rambler.ru
[3] Odessa I.I. Mechnikov National University, 2 Dvoryanskaya Str., Odessa 65082, Ukraine. valyan@onu.edu.ua
[4] Avalon Institute of Applied Science, 976 Elgin Ave., Winnipeg, MB, Canada R3E 1B4
valyan@avalon-institute.org

Keywords: Messinian Salinity Crisis, Paratethys seas, Manych, Bosporus, Dardanelles and Gibraltar straits

Introduction

In the Miocene, during the time interval from 12 to 5 million years ago, global hydrodynamic and lithodynamic processes occurred in the Caspian-Mediterranean region, the consequences of which were generally positive for the development of modern civilization. These include several time-shifted processes of formation of the Paratethys seas and their sudden disappearance; the formation of the Bosporus, Dardanelles, and Manych straits; evaporation of water in the Mediterranean Sea and its secondary infilling with ocean water; the formation of the Gibraltar Strait; vertical movements of the earth's crust caused by changes in pressure on the bottom of the Mediterranean Sea; and the formation of the deep-sea basin of the Black Sea. All these processes were interrelated and exerted a certain influence on each other. In the 1970s, a mathematical model that described the main changes in the Mediterranean Sea and the formation of the Gibraltar Strait during the Messinian Salinity Crisis was developed (Yesin [Esin] et al., 1986, 1987). In recent years, a model describing the flow of freshwater from the Black and Caspian seas into the Mediterranean based on new geological material has been proposed (Garcia-Castellanos et al., 2009). A model for the formation and subsequent disappearance of the Paratethys seas was also recently presented (Esin et al., 2016). In the present report, these processes are shown in their geologic sequence, and their mutual influence is considered, taking into account the action of physical laws.

The dynamics of the level of the Paratethys seas, the formation of the Bosporus, Dardanelles, and Manych straits

The first Sarmatian Sea was formed in a vast depression around the Black and Caspian seas. The exit of water from this depression was closed by a mountain range with a height of about +120 m relative to the current level of the ocean. During the melting of the glaciers, the depression was filled by water to the minimum elevation of the mountain ridge. In the process of further water flow into the sea, water began to pour over the mountain into the Mediterranean Sea. The stream of water formed the bed of a river, which crossed the mountain range. The elevation of the river bed actually controlled the water level in the Paratethys seas.

Note, that only fresh water came into the Paratethys seas. Calculations show that if salty water from the ocean had penetrated into the depression, then its bottom would have been covered by a salt layer with a thickness of hundreds of meters by now.

The Messinian Salinity Crisis in the Mediterranean Sea

The Mediterranean Sea is a basin with a large negative value for its freshwater balance. At present, it is –1700 km^3/year. The sea was being replenished with water from the Atlantic Ocean. Before the Messinian crisis, water flowed into the Mediterranean Sea through straits in the north of Africa. But approximately 5.6 million years ago, these straits were covered with sediment and ceased to exist. According to modern concepts, the drying of the sea began 5.6 million years ago and ended 5.33 million years ago (Garcia-Castellanos et al., 2009), then the sea was refilled with Atlantic water through the new Strait of Gibraltar.

A powerful flow of freshwater in the Dardanelles Strait with the penetration of the Akchagyl fauna (3.3–1.8 million years ago) was investigated (Taner, 1982). This discovery was difficult to explain because it contradicted other geologic evidence. But in fact it is not mysterious. By the time of the Akchagyl transgression, the straits of the Bosporus and Dardanelles already existed, and through them Black Sea water freely flowed into the Mediterranean Sea. In order for this to happen, it was not necessary to raise the level of the Caspian Sea to +100 m. Water could flow and at a lower level. By the results of our calculations, the level of this sea could be at levels from +50 to +80 meters.

Based on results from drilling and seismo-acoustic investigation in the Gibraltar Strait, Garcia-Castellanos et al. (2009) presented a very interesting conclusion about the extremely rapid filling of the Mediterranean Sea by ocean water after the Messinian Salinity Crisis. According to their ideas, the erosion of the bottom of the strait could have reached 0.4 m per day, and the rate of rising in the Mediterranean Sea level could have been 10 m per day. A drawback in the calculations is as follows: if the current level of the Mediterranean Sea had quickly dropped by 1500 meters, then flow of water through the cross section of the Gibraltar Strait of 10000 m x 200 m would have poured from the ocean into the Mediterranean Sea, which could raise the sea level at a rate of up to 10 m per day. But the process was really different. At first, water filled the Mediterranean Sea from two rivers, the sections of which are represented in Fig. 1.

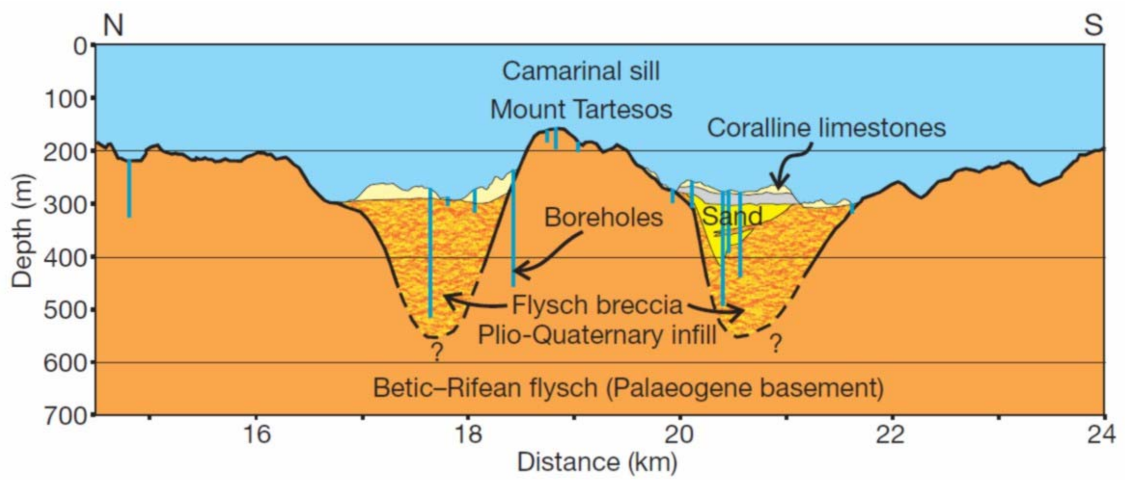

Figure 1. Seismo-acoustic section across the Strait of Gibraltar. Readily visible are the channels of the two rivers and the general rectilinear section through the strait.

Then, the width of the strait began to increase due to the appearance of a rectangular section of the strait. At this stage, the flow of water in the strait increased sharply, and the water levels in the ocean and in the sea could be equalized. At this point, the unilateral flow stopped: when the depth of the strait was not 200 m (as now) but, for example, 50 m. From the theory of "rapid" filling of the sea follows that a layer of evaporites up to 3 km thick could not have formed in a few months. This requires hundreds of thousands of years of water evaporation. Consequently, if the theory of the "rapid" filling of the Mediterranean is recognized as correct, then it should be assumed that a layer of evaporites was formed during the slow closure of straits passing through northern Africa.

The mutual influence of the Mediterranean, Black, Caspian, and ancient Paratethys seas on each other

Some interaction between the Paratethys and Mediterranean seas began about 10 million years ago, when the level of the Sarmatian Sea rose above the mountain between the Black and Mediterranean basins and "fresh" water flowed into the Mediterranean Sea. At this time, the erosion process began, as a result of which the straits of the Bosporus and Dardanelles were formed. The Mediterranean Sea actively assisted this process. Its level performed periodic glacioeustatic fluctuations with an amplitude of about 100 m. Due to this, the basis of erosion was periodically increased, which initiated the process of deepening the bottom of the straits, i.e., the process of erosion in the straits.

When the bottom of the straits fell below the transgressive level of the ocean, the flow of freshwater in the strait increased, approximately, from 100 to 200 km^3/year and more. With this magnitude of freshwater inflow in the eastern part of the Aegean Sea, there was a strong freshening of water and a freshwater fauna appeared.

During the Messinian Salinity Crisis, a considerable amount of freshwater flowed into the eastern basin, and the area of the formed lake varied from 100,000 to 200,000 km^2.

Hypothesis on the mechanism of the deep Black Sea basin formation

Many geologists studying the geology of the Black Sea conclude that the Black Sea basin was formed about 5 million years ago (Muratov, 1975). Before that, the sea was shallow. In our opinion, the creation of a deep-water basin is connected with the Messinian salt crisis of the Mediterranean Sea. During the drying of the sea, the pressure on the bottom decreased, and it began to rise. At the same time, the bottom dragged the magma from neighboring areas from all directions. This created a negative pressure, which led to the immersion of the coast. This pressure dragged the earth's crust beyond the sea down. Thus, a force directed downward operated on the earth's crust. This force, together with the force of gravity, overcame the frictional force, and in the present territory of the Black Sea, there was a rapid slide down a huge mass of precipitation (crustal depression). Precipitation fell several kilometers, creating a deep basin with area of about 400 thousand km^2. Thus, we hypothesize that, in this process, an important role was played by the forces created during the rising of the Mediterranean Sea bottom.

Conclusions

This article analyzes the impact of the Paratethys seas, and later, the Black and Caspian seas, on the evolution of the Mediterranean Sea. It is shown that these seas supplied freshwater to the Mediterranean Sea from the middle Miocene to the Holocene. During the Messinian Salinity Crisis of the Mediterranean Sea, in the eastern basin of this sea, there was a lake of freshened water with an area of 100 to 200 thousand km^2. The results obtained with regard to freshwater intake are in full agreement with the conclusions of the article by Çağatay et al. (2006), which was based on evidence from geologic materials. We propose that local rivers could not make a significant contribution to the water freshening in the eastern basin of the Mediterranean Sea. At all stages of the development of the Mediterranean Sea, the main contribution to freshening was made by waters entering this sea from the Paratethys seas. It should also be noted that only freshwater flowed into the Paratethys seas (beginning from the formation of the closed Sarmatian Sea). If water from the oceans were to enter them, a layer of salt would have formed on the bottom of the Paratethys seas, as was the case in the Mediterranean Sea during the Messinian Salinity Crisis.

In our opinion, the deep-water basin of the Black Sea was formed during the Messinian Salinity Crisis as a reaction to vertical movements of the earth's crust. The report also shows the mechanism of strait formation as well as the mechanism for the formation of the deep-sea basin of the Black Sea.

Acknowledgments

This study was funded by RFBR according to the research project № 16-35-00441 mol_a. This is a contribution to the IGCP 610 project "From the Caspian to Mediterranean: Environmental change and human response during the Quaternary."

References

Çağatay, M.N., Görür, N., Flecker, R., Sakınç, M., Tünoğlu, C., Ellam, R., Krijgsman, W., Vincent, S., and Dikbaş, A., 2006. Paratethyan–Mediterranean connectivity in the Sea of Marmara region (NW Turkey) during the Messinian. *Sedimentary Geology* 188–189: 171–187.

Esin, N.V., Yanko-Hombach, V., and Esin, N.I., 2016. Evolutionary mechanisms of the Paratethys Sea and its separation into the Black Sea and Caspian Sea. Quaternary International DOI: 10.1016/j.quaint.2016.06.019

Garcia-Castellanos, D., Estrada, F., Jiménez-Munt, I., Gorini, C., Fernàndez, M., Vergès, J., and De Vicente, R., 2009. Catastrophic flood of the Mediterranean after the Messinian salinity crisis. Nature 462(7274): 778–781.

Muratov, M.V., 1975. Osnovnye etapy istorii razvitija oblastei, okruzhaushih Chernoe more [The main stages of the development history of the areas surrounding the Black Sea]. In *Zemnaia kora i istoria razvitia Chernomorskoi vpadiny* [*Earth's Crust and History of Development of the Black Sea Basin*], pp. 125–131. Nauka, Moscow. (In Russian)

Svitoch, A.A., 2014. *Bol'shoi Kaspii: stroenie i istoriia razvitiia* [*The Great Caspian Sea: Structure and History*]. Moskovskii gosudarstvennyi universitet imeni M.V. Lomonosova, Moscow. (In Russian)

Taner, G., 1982. Die molluskenfauna und pliorane stratigraphie das halbinsel gelibolu [The mollusk fauna and pliorane stratigraphy of the Gelibolu peninsula]. *Communications de la faculté des sciences de L'Université d'Ankara, série C1, Géologie* 25: 1–27. (In German)

Yesin (Esin), N.V., Dmitriyev, V.A., Shimkus, K.M., and Ovchinnikov, I.M., 1986. A model for the messinian events in the Mediterranean sea. *International Geology Review* 28(1): 10–14. DOI:10.1080/00206818609466245

Yesin (Esin), N.V., and Dmitriyev, V.A., 1987. On the possible mechanism of formation of the Messinian evaporites in the Mediterranean Sea. *International Geology Review* 29(3): 258–263. DOI: 10.1080/00206818709466143