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THE HISTORY OF THE FORMATION OF MACROZOOBENTHOS OF RIVERS IN AZERBAIJAN

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Abstract. The article provides an overview of history of development for macrozoobenthos, which is an integral part of hydro fauna. At the same time, information is provided regarding the transgression of hydro fauna of Kura River over the Oligocene period of Cenozoic era.

Keywords: *hydro fauna, Caucasus, Pliocene, Oligocene.*

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It is known that macrozoobenthosis an essential part of hydro fauna; therefore we have studied the hydro fauna of Kura River, which is an integral part of Azerbaijan over the long historical period.

The hydro fauna of Azerbaijan includes various faunistic complexes formed under the influence of the physical and geographical environment of the country and its relationship with the aquatic faunas of neighboring territories and the Caspian Sea during the Neogene and Post-Pliocene. Because of the diversity of these reservoirs, various genetic groups of animals were found in them, the main part of which inhabited in reservoirs in different geological periods of the formation of the Kura basin.

The history of the formation of the Kura freshwater fauna reflects the features of the long and complex geological history of the Caucasus, as well as the transgression of the Southern Russian seas during the Cenozoic era (Bertotti *et al.*, 2002).

The zoogeographic analysis of the fauna, the ecological characteristics of individual species and the comparison of modern and fossil fauna are also of great interestin order to unveil the history of the formation of the Kura hydrofauna. Materials on the remains of freshwater animals found within Azerbaijan, the Caucasus, and neighboring countries are provided below.

On the site of the modern Caucasus, the land was still in the Paleozoic, as evidenced by the abundant remains of plants of the Carboniferous flora found in the sandstones of the northern slope of the Main (Glavny) ridge (Vereshchagin, 1959). In the Jurassic and Cretaceous, there were separate islands covered with ferns, cycads, and woody vegetation on the Caucasian continent. For that time, freshwater reservoirs did not yet exist on the islands of the Caucasian continent, and therefore no freshwater animals existed.

In the Paleocene, the waters of the Tethys flooded southern Europe, Ukraine, Crimea and partly the Caucasus, merging with the Asian Sea. The Eocene for the Caucasus is characterized by potent volcanic eruptions, because of which the Caucasian island rises among the Tethys and acquires a mountainous relief. In the Oligocene

epoch, an essential part of the Main Caucasian ridge was still below sea level, which reached a pretty significant depth, as evidenced by the Maikop deposits, which are widely developed in Azerbaijan. At the end of the Oligocene, mountain-formation movements began, and consequently, mountain folds emerged from under the water level. At this time, the main features of the Caucasus were finally formed.

In the Oligocene, the Caucasian Island had a tropical climate, as evidenced by the presence of remains of ferns in, palms, conifers and others in the tuff-sandstone sediments of Darry-Dag in the Aras valley close to Julfa. Continental deposits with freshwater fauna were also not found in the Oligocene layers. Findings of mammalian fauna and flora indicate that in the Oligocene there was a continental connection between the Lesser Caucasian landmass with Central Asia and Central Asia, as well as with Western Europe.

In the Lower Miocene, the Caucasian was sharply stretched from about Anapa to the upper reaches of the Samur. In the area of the Dzirulsky crystalline massif, there was another smaller island. At the end of the Miocene, land also appeared around Trialeti-Akhaltsikh and Borjomi. The Kura lowland was a deflection occupied by the Middle Ioinian and Sarmatian seas. In the Middle Miocene, the Caucasian Island gradually rises and becomes a peninsula adjoined to the Near Asian massif. The climate of the peninsula was subtropical, since the vegetation consisted mainly of representatives of subtropical species (There were also plains with well-developed forests, shrubs, lakes, and quiet river backwaters, overgrown with abundant marsh vegetation, which was the feeding base of the platybelodonts on Caucasian Peninsula, along with mountain ranges (Vereshchagin, 1959). Freshwater animals also lived in the reservoirs of the Miocene era. V.V. Bogachev found freshwater mollusks - Cyrena, Melanopsis, Congeria, Planorbis in the Miocene, in the Aquitanian layers of Akhaltsikh and Borjomi (1931). There were freshwater lakes and rivers, with a fairly rich fauna of Unio, Viviparus, Planorbis in the North Caucasus, around the region of the Stavropol Plateau; however, such freshwater deposits have been preserved most of all in the Transcaucasia. Freshwater mollusks Unio, Viviparus and Malanopsis were found by V.V Bogachev (1961) in the Sarmatian deposits of brown coal of Iori river,in the Kidurma tract. Freshwater paleontological finds in the Kura basin are also known for the Miocene oncophorus layers from Gori to the Caspian Sea and in the spaniodont beds of Georgia (Bogachev 1936; Zhadin, 1952); these were Melanopsis, Unio, Planorbis, etc.

Also, Anodonta, Unio, Limnaea, Plonorbis, Theodoxus, Melanopsis were found in the Pliocene, in the valley of the Kura river, also between the Aras and the Euphrates,whose representatives still live in the Kura basin (Zhadin, 1952). V.V. Bogachevindicated a variety of Unionidaefor the Tertiary deposits of the Aras River. Unio erevanicus, U.rozdanicus, Melanopsiskleini, Hydrobia, and Limnaea were found in the Upper Sarmatian deposits of the riverZangi (Hrazdan). This fauna, according to V.V.Bogachev (1961), penetrated into the brackish basin of the Upper Sarmatian period along the depression of the Middle Aras. It is interesting that in the layers of marls of the Karaganian stage (Miocene) near Stavropol, numerous insects were found, carried here by small streams to the shallow freshened estuaries of the northern coast. Aquatic forms include mayflies, dragonflies, water striders, water beetles Dytiscidae, Hydrophilidae, caddis flies, and dipterans. In the Upper Sarmatian, the sea reduced in size, and in the south from Kutaisi to Telavi a wide isthmus grew, connecting

"Yafetida" with the Lesser Caucasian land, and in the eastern Transcaucasia a narrow Kura Bay was formed.

At the end of the Miocene, the sea washing the Caucasus began to grow shallow and freshened, and the Caucasian land expanded. According to N.K. Vereshchagin (1959), in the Upper Miocene in the Caucasus there was no hypothetical series of glaciations, about which S.A.Kovalevsky wrote (1936). Consequently, the assumptions of geologists about the destruction of all tropical flora and fauna of the Caucasian land by the Upper Miocene glaciation are not supported by paleontological data. In the Lower Pliocene, the Caucasian Peninsula had a connection with Western Asia and was washed by a slightly saline sea that did not join the ocean (Andrusov, 1918). The Kura Bay had a great depth, which compensated for the significant uplifts in the region of northern Azerbaijan. At the beginning of the Pliocene, the climate of the Caucasian land remained rather warm, but on the rivers of the Russian Plain there were freeze-ups. At the end of the Pontic Age, the sea completely receded from the North Caucasus (Ciscaucasia) and survived only in the place of its southern basin. Purely freshwater fish, paludin mollusks and Unio were found in the Pontic limestones of Odessa (Pavlov, 1936). The vertebra of the catfish Silurusglanis was found in the productive strata at st.Lokbatan (Burchak-Abramovich, 1951). Silurusglanis and freshwater mollusks-Unio, Anodonta, Melanopsis, Hydrobia, Limnaea, Planorbis and Ancylus were found in the Balakhany continental sediment of the Lesser Caucasus, Absheron and Gobustan (Bogachev, 1961).

In the Cimmerian age, the climate was close to the tropical one and a continental connection appeared between the Caucasian Peninsula and the Russian Plain.

There was a narrow Kura Bay in Akchagyl, reaching almost to Tbilisi. The rivers of the Caucasian ridge flowed into this bay. K.A. Alizade (1954) indicated Planorbis sp. for the Akchagyl deposits of Svechino station, south of the Red Wells on the right bank of the river Alazani; in the area ofKarasakhkal region, on the banks of the Kura River and in other areas of the Kura basin numerous Unlo, Anodonta, Sphaerium, Corbicula fluminalis, Valvatapiscinalis, Planorbis, Vivlparus, Odonata, Astacus were found. In the upper Akchagyl layers of Mount Palantokyan near Mingechaur, V.V.Bogachev found the remains of freshwater Cyrinidae. N.A. Kudryavtsev (1932) noted the mollusk Planorbis for conglomerates of the Akchagyl stage in the area between the Kura and Alazani rivers. At this time, numerous freshwater mollusks: Unio, Anodonta, Pisidium amnicum, Sphaeriumrivicola, Valvatapiscinalis, Vlviparus fasciatus, Planorbis were found in the Akchagyl deposits of the riverBelaya(Bogachev, 1961). In the Absheron age, the Kura Bay reached Kirovabad (modern Ganja) and the Taribani steppe. The climate remained the same as in Akchagyl. In the Absheron Age of the Caspian, V.P. Kolesnikov (1939) found Corbicula fluminalis, Radix lessonae, Anodonta, Unio, Melanopsis. According to this author, C. fluminalis came to the desalinated Absheron basin from rivers and lakes. At the end of the Absheron peninsula, the ancient mountain ranges of the Greater and Lesser Caucasus were leveled. Considering the detailed substantiation of NK Vereshchagin (1959), we also believe that on the Caucasian land there were only glaciers of a valley nature. This opinion is consistent with the paleontological data and analysis of the modern fauna of freshwater reservoirs in Azerbaijan.

In the Upper Lavantin (Absheron) deposits in the river Sal, the remains of a crayfish, Astacus leptodactylus were found in the lower reaches of the Don.

N.K. Vereshchagin (1959) in the continental deposits of the Taman Peninsula near Kuchugur and in the upper Apsheron layers of eastern Transcaucasia found the remains of terrestrial mollusks Chondrula, Helix, freshwater-Corbicula, Anodonta, etc. According to N.K. Vereshchagin, Pleistopene glaciers occupied only the upper parts of the valleys, not even reaching the Rocky Range. Consequently, there were no fundamental differences in valley glaciers in comparison with modern times. The author writes that "the alpine vegetation in the Ice Age was shifted downward, but by no means completely displaced to the foothill plains." As for the traces of hypothetical glaciations in the form of pebbles and boulders on the foothill plains, they were introduced during floods and volcanic eruptions, and in different time.

In the Quaternary sediments of the Binagadi conservation on Aиsheron, A.V. Bogachev (1947) described the remains of aquatic beetles – Dytiscus circumtlexus, Cybisterlaterali marginalis, (jyrinus caspius. Remnants of freshwater animals are also known for the Quaternary lacustrine sediments of Armenia near Khamur-Dag, the Pasinsk valley and the valley of Euphrat. Here were found Unio tumidus, Viviparus viviparus, Melanopsis, Limnaea ovata, L. palustris, Valvatanaticina, Pyrgula, Planorbis corneus, Pisidium, Sphaerium (Bogachev, 1961). In the brown coal layers of the northern outskirts of Tabriz, V.V.Bogachev discovered Limnaea stagnalis and Anodonta mutabilis, indicating a cooling wave that made it possible for boreal species to penetrate far to the south. This corresponds to the pluvial epochs of the Mediterranean in North Africa, well connected with the glaciation of M.R.N. A stunning fact is the finding of A.D. Aliev (1961) in the artesian source and stream of the foothill zone of the eastern extremity of the Lesser Caucasus, between Barda and Agdam of a living fossil about the Quaternary mollusk of Europe Pisidium vincentianum. This species was first described in 1913 by V.V. Woodward (Woodward, 1913) from the Pleistocene of Belgium, then in the Pleistocene deposits in Kent, at the beginning of the Holocene in Down (England), and in the Pleistocene and Holocene of Denmark and Germany. In 1914, V.V. Woodward found it in collections of modern mollusks from Central Asia. Thus, the presence of Pisidium vincentianum in the foothill zone of the Lesser Caucasus also indicates that in the Caucasus in the Quaternary period there was a temperate climate in which various groups of freshwater animals lived in water bodies.

Based on the analysis of paleontological data, it can be concluded that the formation of the Kura freshwater fauna began in the Lower Pliocene, when the Kura Valley was formed. This is also consistent with the paleontological data and opinion of A.N. Derzhavin (1951). A similar opinion regarding fish was also expressed by Y.A. Abdurakhmanov (1960, 1962). According to A.N. Derzhavin, "the main most ancient part of the water population of Azerbaijan was formed from different elements no later than the end of the Pliocene-beginning of the post-Pliocene." V.D. Lebedev (1960) came to almost the same opinion when analyzing the Quaternary freshwater ichthyofauna of the European part of the USSR. The author points out that all modern genera of fish were formed at the end of the Miocene, and all modern species of ichthyofauna of freshwater bodies were formed at the end or middle of the Pliocene. The basis of the modern ichthyofauna of the European part of the USSR is the Tertiary Ponto-Caspian ichthyofauna that developed from the fauna that L.S. Berg (1940) called the ancient Upper Tertiary fauna, and which was distributed circumboreally. Remnants of the warm-water part of this fauna are now found in the fresh waters of the European part of the USSR, in North America and in the Amur basin.

At the end of the Pontic period, the rivers of the Caucasian land were enriched with Palaearctic species penetrating from the north through the Caucasian Isthmus. V.I. Zhadin (1952) came to the same conclusion when analyzing the origin of a significant part of the Palaearctic mollusk species of the Caucasus.

Analysis of the fauna of freshwater bodies of Azerbaijan indicates that the bulk of it is made up of animals (Palearctic, Holoarkts), widespread before the Pliocene in the northern part of the globe. In the preglacial period, representatives of the Upper Tertiary freshwater fauna had a continuous range. Later, under the influence of the Ice Age, they were destroyed and survived only in areas not affected by glaciation, as well as in places that maintained a temperate climate during the ice age. Such fauna examples were Talysh, western Transcaucasia, Manchuria, Japan, the Atlantic states of the USA (Berg, 1940). Such were the modern territory of Azerbaijan and the countries located around the Mediterranean Sea.

Judging by the literature data, in the freshwater bodies of Azerbaijan before the Pliocene, in addition to unionids and melanopsis, there were also some small and thin shell mollusks (Bogachev, 1938), the remains of which have not survived to our time. These small mollusks, in our opinion, lived in cold and muddy rivers, poor in calcium compounds, with low temperatures and strong water currents. Subsequently, these mollusks participated in the settlement of the Kura tributaries. As the seas regressed, the rivers descended into the foothills, these parts of the rivers were inhabited by such ancient mollusks. In the lower reaches of rivers, due to a decrease in the speed of water flow, an increase in temperature and calcium content, they thickened their shell and size. Therefore, since the Pliocene, their shells have been found in the freshwater deposits of Azerbaijan. We believe that these mollusks were the ancestors of the modern endemics of the Caucasus and Azerbaijan (Theodoxus subthermalis, Pyrgula sieversi, Unio sieversl, etc.) and the species Theodoxusfluviatilis ,, T. danubialis, Ancylus fluviatilis, Hydro bialongiscata, which, as before, live in springs and spring streams in the foothill zone of the Lesser Caucasus. All this ancient complex of mollusks was in the zone of the lower and part of the mountain forests within the terraces of the Quaternary seas from the Absheron to the Caspian. We believe that in the Caucasus, endemic species were formed in water bodies of mountainous and foothill zones, where, because of climatic changes, there were suitable conditions for the emergence of new species.

Of these species, Ancylus fluviatilis could survive the glaciation zone in lakes, according to V.I. Zhadin (1952). To his opinion, "during the glacial period A. fluviatilis lived not in rivers, but in lakes, since in arctic conditions they still migrate from rivers to lakes".

As mentioned above, there were glaciers of a valley character, similar to modern ones in the Caucasus during the Quaternary period. We believe that in the Greater Caucasus, the climatic conditions and hydrological regime of the rivers were worse than in the Lesser Caucasus. It can be assumed that the freshwater animals of Azerbaijan survived the cooling of the Ice Age climate mainly in the springs and spring streams of the foothill zone of the Lesser Caucasus, as evidenced by the diversity of the species composition of the mollusks of the Gargarchay river (formed in the Oligocene) of the Lesser Caucasus in comparison with the rivers of the Greater Caucasus.

As for Radix auricularia morphalagotis and Galba truncatula, which live in the rivers of the Greater Caucasus, the time of their penetration may be the postglacial epoch since they live in the same springs and reservoirs where Pisidium casertanum is

located. However, Radix auricularia is ecologically more plastic than the other two species.

The most ancient Pliocene animals of the Kura basin were endemic. According to A.N. Derzhavin (1951), the first invaders of the Kura were a group of freshwater fish derived from the Upper Tertiary fauna that developed in the South Russian seas. Among the fishes of the freshwater bodies of the Kura, Neogobius cephalarges constructor also belongs to the ancient Pliocene forms. Concerning the origin of the goby N. cephalarges constructor, V.V. Bogachev stated: "in the Sarmatian age or the Akchagyl transgression age, the main marine species penetrated into the transparent rivers of the Caucasus with a rocky bottom, and then in the era of regression, when sections of the lower reaches of the rivers formed on the former bottom sea plains, such conditions were created that the gobies could not return to the sea, and their habitat turned out to be in the mountains".

The Near Asian species penetrated the Caucasus in the Lower Pliocene, when the Caucasian Peninsula had a connection with the Near East. The time of penetration of Arctic species can be attributed to the postglacial era.

The time of penetration of Mediterranean species into the Caucasus mustbe attributed to the end of the Pliocene. However, some fish species of Mediterranean origin (atherina, needlefish, goby-bubyr) entered the Khvalynskoe Sea through the Manych from the New Euxinian or Old Black Sea basin (Derzhavin, 1951). According to the mentioned author, they moved got here with the help of the Absheron transgression together with a dolphin and a scyenna.

Tropical and subtropical species (Potamonpotamios, Corbicula fluminalis, Daphnia lumholtzi, etc.) penetrated freshwater bodies of Azerbaijan from the south and southeast in the Lower Pliocene, when the Caucasian land has the linkage with Western Asia. So, Corbicula fluminalis could penetrate the Kura basin from the reservoirs of Syria along the valley of the upper reaches of the present river. Euphrates. In the Pliocene, on the Russian Plain, there were freeze-overs, which caused torrential rains over what is now the Mediterranean. The amount of these torrential rains (pluvial epochs) corresponds to the amount of freeze-up. Apparently, during this period, the upper reaches of the Euphrates and the Kura were repeatedly connected with each other.

Among the tropical elements, Potamonpotamios lives exclusively in the springs and spring streams of the foothill zone with a pebble and rocky bottom, rising to an altitude of *1000 m*.

Regarding the origin of tropical and subtropical elements of Central Asia, we may state that they penetrated into Central Asia in the postglacial era (Zhadin, 1948). V.I. Zhadin notes that one of the groups of tropical and subtropical fauna penetrated into Central Asia in the Tertiary time, and the second, which currently lives in shallow water bodies and in rice fields, in the postglacial time.

The Ponto-Caspian fauna of the Kura and water bodies of its valley is a relic of the post-Khvalynian epoch, which include: Pontogammarus robustoides, P.sarsi, Limnomysis benedeni, Pomatoschistus caucasicus, Proterorhinus marmoratus and others. At present, the fact of the presence of Pontogammarus robustoides Abrau is obvious, which allows us to ascribe to them at least a Lower Quaternary age (Derzhavin, 1951). According to the author's opinion, "the wide adaptation of the Ponto-Caspian crustaceans to a wide amplitude of water salinity ensured them in the past great chances of surviving with fluctuations in the salinity of Quaternary water bodies". In the light of existence of such facts, the species stability of a number of Caspian crustaceans in the relict section of the Black Sea rivers from the pre-

Khvalynian time is not surprising. A more accurate determination of the age of these components is very difficult, since the connection of the Caspian with the Black Sea along the Manych and the possibility of fauna exchange during the Quaternary time was established repeatedly, possibly up to 6 times.

Same as A.N. Derzhavin, regarding the distribution of the Ponto-Caspian elements in the Kura, we believe that they previously lived in the Kura Bay of the Quaternary or Pliocene seas and moved to freshwater habitation in situ as the bay was filled with river sediments (Akbayram *et al.*, 2017). According to this author, Astacus leptodactylus, from the Ponto-Caspian relict fauna, lived in the Akchagyl Bay of the Caspian Sea, and after the formation of the lower course of the Kura, it remained in the area.

The ability of the Ponto-Caspian amphipods to bury themselves in the sand (for example, Pontogammarus sarsi) developed in the subsequent period of adaptation of the species to its environment. In this case, apparently, it was a rescue from the direct destructive influence of suspended sediments and currents. Having adapted to burrowing, P. sarsi, firstly, receives food in the form of organic detritus and bacteria, and, secondly, it is protected from drift downstream and the influence of suspended solids. As a result of the constant influence of the flow factor and burying in the sand, the body of P. sarsi acquired a slender shape, which cannot be said about Pontogamarrus robustoides. The latter is confined mainly to a narrow strip of the riverbank, where it escapes from drift and water flow.

Most recently, the Kura River was settled by colonists from the river basins of the North Caspian. These include bream, sabrefish, tench (doctor fish), sunbleak (belica), Northern pike, perch, sander (pike perch). They inhabit the same water bodies as the Ponto-Caspian elements, without crossing the borders of the Kura-Aras lowland (Derzhavin, 1951; Abdurrahmanov, 1962). The penetration of northern elements into the Kura occurred when in the Upper Pliocene epoch (more precisely, in the Cimmerian age) the northern and middle parts of the Caspian did not exist, and the Volga flowed into the southern Caspian basin in the region of the Kura delta, and the deltas of these rivers were in contact. Apparently, at this time the northern species penetrated the lower reaches of the Kura River.

Based on the above-mentioned issues, we may conclude that freshwater animals already lived in the reservoirs of the Caucasian Peninsula during the Miocene epoch. The modern freshwater population of Kura River was formed in the Lower Pliocene. Currently, studies regarding the existing status of use of transboundary water resources of Kura River and the upcoming perspectives are continued (Imanov, 2019).

In recent years, an encyclopedia of hydrology inhabiting the fauna of Azerbaijan has been compiled (Ahmadzadeet.al, 2016.). Also, Alakbarov (2011) studied the formation of infusers in the freshwater basins of Azerbaijan. The formation of parasitic fauna is continuously studied by Sh. Ibrahimov (2018).

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