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UPPER MIOCENE FAUNA OF OREŠAC NEAR SMEDEREVO (SERBIA)

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Near Smederevo, Orešac is one of the important Neogene localities described in literature, but it has not been preserved. During recent years, the field studies of the vicinity of Smederevo have shown that there are other preserved rich fossil sites with a mass appearance of the species *Mytilopsis triangularis* (Partsch) and *Dreissena auricularis auricularis* Fuchs and representatives of the family *Lymnocardiidae.* The most representative localities are Sastavci, Orešac-Udovice and Orešac-Udovice (New road to Požarevac). The site at Sastavci was described as a locality of particular importance for determining the stratigraphic characteristics of this part of Central Paratethys, as it represents a direct continuation of the layers previously described as a faciostratotype of Upper Pontian under the name Orešac I. The locality Orešac-Udovice (New road to Požarevac) was described as the highest level of "Danube type (Groča-Smederevo) of development" of Upper Miocene.

Key words: Orešac-Udovice, Sastavci, Upper Miocene fauna, geoheritage.

INTRODUCTION

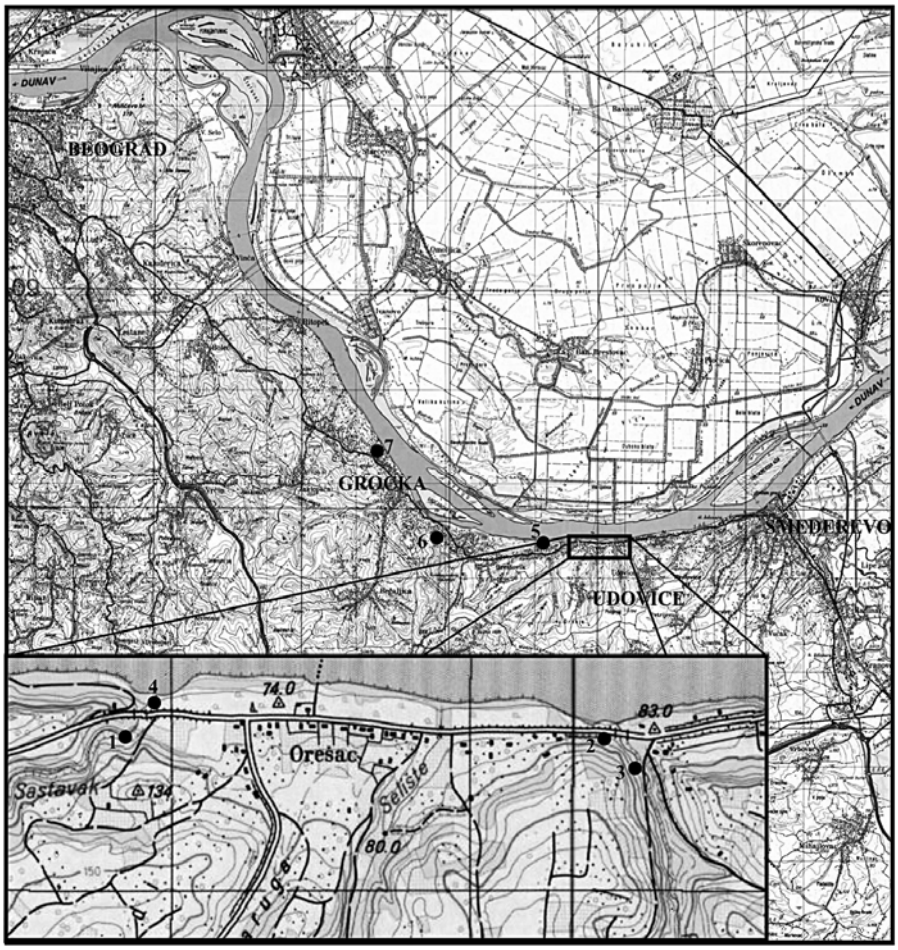
For about a hundred years stratigraphers and paleontologists have researched and debated the stratigraphy of the younger Neogene, especially the correlation of strata between the large separated sedimentation basins (Central Paratethys and Eastern Paratethys). Alongside the classical stratigraphic methods such as lithological (sedimentological), tectonic, and biostratigraphic-paleontological (based on studies of macrofauna, microfauna, and microflora), recently there has been an increase in new methods: geophysical (paleomagnetic), new paleontological (nannoplancton, dinoflagellates etc.), radiometric dating, etc. However, in spite of the introduction of new methods and additional development of the old ones, there are still numerous unsolved problems in defining the age and correlation of Neogene sediments.

To find needed correlations in the stratigraphy of Neogene, stratotypes and facial stratotypes are used as etalons for comparing the synchronic Neogene sediments in characteristic profiles where the corresponding Neogene sediments are well-developed and rich in paleontological material. During the field work in Serbia, a facial stratotype for the Portaferian substage of the Pontian (younger Upper Miocene) of Paratethys was determined in the vicinity of Smederevo as a "Danube type" of development (Stevanović 1951**,** Stevanović 1989). According to the cited author, the most important locality with fossils of the Danube type of development of Portaferian is Orešac I.

The studies performed over a century have shown that Pontian sediments cover most of the Danube area near Smederevo. The drilling results have shown that their thickness is about 150 *m* in the vicinity of Grocka and about 300 *m* in the vicinity of Smederevo (Stevanović 1951, Spajić 1977, Knežević *et al.* 1987). Almost all intercalating layers are rich in fossils. The diversity and effective preservation of fossil fauna, as well as its importance in international stratigraphic correlations, motivated new field studies and collecting of fossil material.

The vicinity of Smederevo is characterized by very brittle rocks, prone to erosion. The Pontian sediments are covered by Quaternary sediments with land mollusk fauna (Mitrović 2004) etc. The paleofauna was studied and collected several times during the last several years, leading to a description of two newly formed profiles named Sastavci and Orešac--Udovice (New road to Požarevac) (Map. 1, Fig. 1, 4). The goals of the study were to determine the state of previously and newly discovered

Pontian localities in the vicinity of Smederevo, collect the fossil material, and determine the stratigraphic, paleoecological and taphonomic characteristics of paleofauna. The authors of this paper have performed the first description and detailed research of the described localities. One part of the research was performed in collaboration with the Museum in Smederevo.



Map 1. - Location map of the fossil sites: Sastavci (1); Orešac-Udovice (Udovički potok) (2); Orešac-Udovice (New roud for Požarevac) (3); Orešac I (4); Orešac II (5); Dubočaj (Grocka) (6); Crveni Breg (Grocka) (7).

The material has been stored at the Natural History Museum in Belgrade and in the Museum of Smederevo. The Natural History Museum in Belgrade also includes the collections by Academy Members Petar Pavlović and Petar Stevanović. Part of this material is shown in plate (I, II).

OVERVIEW OF PREVIOUS STUDIES

Due to their richness in fossil material, the Pontian sediments in the vicinity of Grocka have been the subject of research by numerous paleontologists: Brusina 1894; Pavlović 1931; Stevanović 1951; Krstić *et al.* 1992, Jovanović 1988, 1998, 2003, Jovanović and Paunović 2005 etc. They were separated as the layers with *Congeria triangularis* Partsch and placed in the Upper Congerian group. According to the identified species this locality is believed to be of the same age as Radmanest in Banat (Romania). The importance of these layers and layers with *Congeria rhomboidea* Hörnes was discussed by Pavlović (1923). Stevanović (1951) describes the localities Orešac I and Orešac II in detail, placing the sediments into the Upper Pontian (Portaferian), making a correlation of facies and horizons of the whole Paratethys, and discussing the problems of the upper and lower boundary of Pontian.

Over time it was shown that the same sediments were often given different names and this often confused paleontologists. Separation of stage and substage, instead of enabling more successful correlation in a wide international scope, brought more disagreements. The divisions and correlation of Neogene with Tethys and Paratethys were performed through the use of different methods in recent years, while the divisions based on malacofauna were almost completely neglected (Stevanović 1986). The stratigraphic characteristics were determined and correlations between certain localities of Central Paratethys made according to the characteristics of the bivalves (Stevanović 1951, 1978**;** Müller and Magyar 1992 etc.). There were some suggestions about the revisions to the Pannonian-Pontian boundary. However, the question of Neogene divisions remains current to this day. Moving the Pontian stage into the Upper Miocene and its comparison with the Mediterranean Tortonian and Messinian (Rögl and Steininger 1983) would, according to Stevanović (1988), mean that Pliocene would be reduced by several million years, that is, the whole Pontian as defined now. The same author believes that the possible acceptable corrections could only include the Lower Pontian (Novorossian). In spite of the numerous uncertainties, the Portaferrian substage is officially accepted and included in the official stratigraphic division of Paratethys Neogene (Stevanović 1990c). The interest in the correlation of sediments from Late Miocene, their relationships with other basins and evolution and origin of their fauna is ongoing (Popov *et al.* 2006). Some magnetostratigraphic and chronostratigraphic correlations of sediments of Late Miocene were also made (Magyar *et al.* 1999b). The new stage Transdanubian, introduced by Sacchi and Horvath 2002, is considered by some authors to create even more problems.

At many localities in Serbia and Bosnia a mixture of Pannonian and Pontian mollusks was recorded at the Upper Pannonian-Lower Pontian boundary (Stevanović 1979-1980). This boundary was defined by the extinction of one type of large congeria and the appearance of another group of congeria with large shells. The lymnocardiids did not show such great sensitivity, and many species from Pannonian have survived into the Pontian. There are some transitionary mollusk forms: *Mytilopsis czjzeki* (Hörnes) (Upper Pannonian), *M. czjzeki zagrabiensis* (Stevanović) (Lower Pontian), *M. zagrabiensis* (Brusina) (Upper Pontian) etc. (sensu Stevanović 1979-1980). The more detailed stratigraphic divisions according to the biometric analyses of lymnocardiids were made by Müller and Magyar 1992. The examples of gradual evolution among the mollusks were described by Müller and Magyar 1992, Stevanović 1978 etc. According to the basic morphological characteristics of the genera belonging to the family, Dreisseniadae, Harzhauser & Mandić (2010) cite a list of taxa recorded in literature.

Stevanović and Mihajlović (1981) and Jovanović (1988, 1998) have published lists of identified species from certain localities (Požegovački Potok, Orešac-Udovice). The described geological profiles are included in localities very important for Serbian geoheritage. Jovanović (2003) presents the preliminary results of studies at the locality Orešac-Udovice (New road to Požarevac). Jovanović and Paunović (2005) have presented the results of the first studies at the newly discovered locality Sastavci.

Certain authors claim that the Upper Pontian sediments of Grocka--Smederevo Danube area are connected with the Beli Potok Bay (Stevanović 1955) and Samar Hill (Knežević 1990) via Čot Hill**.**

DESCRIPTION OF THE GEOLOGICAL PROFILES

The studied area is dominated by fine-grained sandy sediments. The more detailed sedimentological studies of the sands (pontian sands, sensu Stevanović 1951) in the vicinity of Grocka and Smederevo have shown the existence of a slightly rounded shape. It was concluded that the minerals within the sands are most probably derived from metamorphic and eruptive rocks. The grains were also well-sorted by size. The smallest grains are in the sediments of Upper Pontian (Obradović and Rudolf 1958).

Most localities of Upper Miocene were recorded along the bank of the Danube. The localities of Orešac, Sastavci, Crveni Breg and Dubočaj begin with a layer of sandy clay that belongs to the lowest layer of Upper Congerian layers. The most common other sediments are sands and poorly

cemented sandstones. Their thickness increases toward the south. (Stevanović 1951, 1987, Anđelković *et al.* 1989).

The most instructive profiles, with numerous and diverse remains of fossilized organisms, i.e. flora, gastropods, bivalves, fish teeth and otoliths, were preserved in the area of Orešac near Smederevo. Presently there are three fossil branches: Sastavci, Orešac-Udovice and Orešac-Udovice (New road to Požarevac).

The geological profile of Orešac I (Orešac on the Danube, near Grocka) was described and placed in Upper Pontian (Lower Portaferian) (Stevanović and Mihajlović 1981). The locality of Orešac I, near the bridge, was described as a facies stratotype (Stevanović 1990c). Presently, the locality of Orešac is not exposed on the surface. The newly discovered locality of Sastavci has high significance for the geoheritage of Serbia. It is situated on the right bank of Sastavci Stream, 250 *m* from its confluence with the Danube. The length of the profile is about 30 *m* and the height about 20 *m*. (Fig. 1.).

Fig. 1. - Outcrop of Upper Miocene sediments - Sastavci

On the left bank of the same stream, besides the mollusks there was also a record of otoliths from family Scienidae (Stevanović 1951). The oldest recorded sediments are grayish-blue clays without fauna remains (layer 1), probably representing the lowest Upper Congerian layer, synchronous to the layer of gray clays at the profile of Crveni Breg near Grocka, with the malacofauna from the horizon with *Congeria triangularis* Partsch (Stevanović 1941). Above the clays there is a layer of fine-grained yellowish-gray sands with a small amount of clay (layer 2), with bivalve and gastropod shells. At the contact place of clays and sands there is a

small spring. The following taxa were collected and identified: *Dreissena auricularis auricularis* Fuchs, *Lymnocardium apertum* (Münster), *L. diprosopum* (Brusina), *L.* cf. *diprosopum* (Brusina), *L. zujovici* Brusina, *L. parazujovici* Stevanović. *L. decorum* Fuchs, *Lymnocardium* sp., *Mytilopsis triangularis* (Partsch), *Melanopsis decollata* Stoliczka, *Gyraulus radmanesti* (Fuchs), *Valvata variabilis* Fuchs, *Radix jaksici* (Brusina).

Layer 2 includes an intercalating layer of gray clayey sands (2a), which is about 20 *cm* thick with numerous mollusk shells and fragments. This material is very soft and falls apart easily, so it is very difficult to separate whole shells from the sediment. The following taxa were determined: *Lymnocardium penslii* (Fuchs), *L. schmidti* (Hörnes), *L. scabriusculum* Fuchs, *L. decorum* Fuchs, *Plagiodacna auingeri* Fuchs, *Melanopsis sturii* Fuchs, *Dreissena auricularis auricularis* Fuchs, *D. auricularis simplex* Barbot, *Valvata variabilis* Fuchs, *Melanopsis defensa* Fuchs, *Gyraulus radmanesti* (Fuchs), *Gyraulus* sp.

The fossil remains of fish from the collection by P. Stevanović were determined on this occasion (9 otoliths and 7 individual teeth). The majority of the otoliths are eroded or fragmented juvenile otoliths. All but one of the investigated otoliths belongs to the family Sciaenidae. Four of the otoliths are not suitable to identify as species or genus level. Two of the otoliths show the greatest morphological similarity with *Trewasciaena kokeni* (Schubert) (Schwarzhans 1993). This type was mentioned as "*genus* aff. *Umbrina*" *kokeni* (Schubert) by Brzobohaty (1992). The other two specimens of otoliths have the closest match in the recent species *Umbrina cirrosa* (Linnaeus). The otolith of *Umbrina cirrhosoides* (Schubert) is poorly preserved; the other juvenile sample presumably belongs to the species *Umbrina* aff. *cirrosa* (Linnaeus) (Cziczer *et al.* 2009). Otoliths tentatively assigned to this species have been known since the earliest Pannonian of the Central Paratethys (Brzobohaty in Schultz 2004, Cziczer *et al.* 2009). One otolith is identified as *"genus Gadidarum" ponticum* Weinfurter. Otoliths of this type were first described in the Vienna Basin (Weinfurter in Papp & Thenius 1954). Two conical teeth belong to individuals of family Sciaenidae, while the remaining five match the family Cyprinidae in their morphology, most probably the genus *Barbus* (Böhme 2002).

The geological profile Orešac-Udovice (Fig. 2), previously known under the names Požegovački potok (Udovički potok), used to be characterized by the mass presence of fossils (Stevanović & Mihajlović 1981, Jovanović 1988) but after twenty years its appearance has changed due to erosion. The intercalating layers and lens with numerous fossils (coquina, Fig. 3) have eroded, so the present appearance includes a layer of grayish-

Fig. 2. - Outcrop Orešac-Udovice (Udovički potok)

blue clays with flora (layer 1) topped by a sand layer (about 4 *m* thick) with mollusk fauna. The following taxa were identified: *Lymnocardium schmidti* Hörnes, *L. zujovici* Brusina, *L. parazujovici* Stevanović, *L. apertum* Münster, *L. diprosopum* (Brusina), *L. (Bosphoricardium) banaticum* Fuchs,

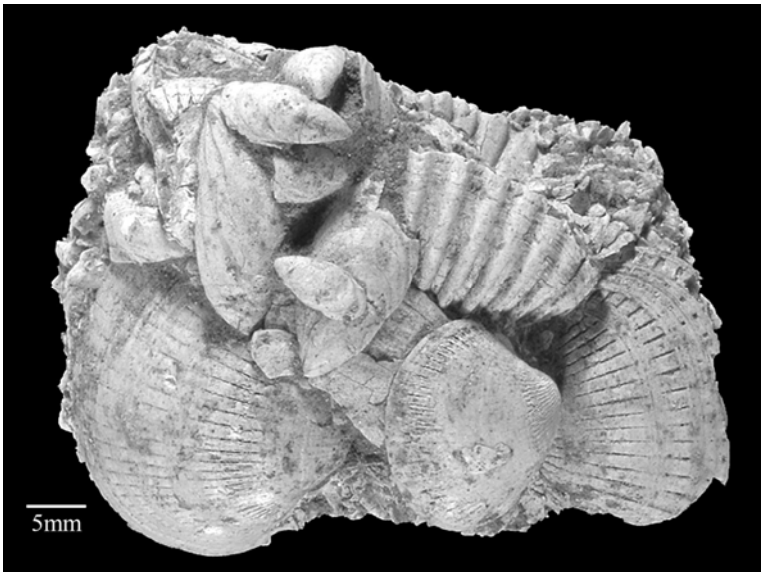


Fig. 3. - A small coquina composed of fragments of large *Mytilopsis triangularis* Partsch and *Dreissena* shells and whole shells of Lymnocardiidae, Dreissenidae etc.

Fig. 4. - Outcrop Orešac-Udovice (New road to Požarevac).

L. penslii (Fuchs), *Lymnocardium* sp., *Phyllocardium complanatum* (Fuchs), *Mytilopsis triangularis* (Partsch), *Dreissena auricularis auricularis* Fuchs, *Valvata variabilis* Fuchs, *Viviparus sadleri* Partsch, *V. viminaticus* Brusina *Melanopsis petrovici* Brusina, *M. decollata* Stoliczka, *Gyraulus radmanesti* (Fuchs), *Gyraulus* sp., *Valvata variabilis* Fuchs. One otolith is identified as *Trewasciaena kokeni* (Schubert).

The best preserved geological profile with paleofauna is situated between Orešac and Udovice, on the right side of the new road to Požarevac (Fig. 4), 100 *m* southwards from the crossroads of lines Beograd-Smederevo and Beograd - Požarevac (Jovanović 2003).

The length of the profile is about 30 *m* and its height about 6 *m*. The profile begins with a layer of gray clays with sparse mollusk fragments. This is overlaid with a layer of fine-grained yellowish sands, about 4 *m* thick, with remains of fossil bivalves and gastropods. The following taxa were determined: *Dreissena minima* Brusina, *D. auricularis auricularis* Fuchs, *Lymnocardium zujovici* Brusina, *L. parazujovici* Stevanović, *L. secans* (Fuchs), *L. diprosopum* Brusina, *L. decorum* Fuchs, *Phyllocardium complanatum* (Fuchs), *Mytilopsis triangularis* (Partsch), *Valvata variabilis* Fuchs, *Viviparus sadleri* Partsch, *Viviparus viminaticus* Brusina *Gyraulus radmanesti* (Fuchs), *Melanopsis decollata* Stoliczka, *M. petrovici* Brusina, *Micromelania klaici* Brusina. The sand layer includes a small bank of hardened sediments with an increased ratio of grayish calcium carbonate, about 15 *cm* thick. The fossil coquina is common (Fig. 5), with fragments

of frail, easily breakable shells of limnocardiids and dreissenids. The other fauna is represented by the species recorded in the sandy layer.

Fig. 5. - Coquina consisting mostly of damaged mollusk shells tightly glued with cement material: *Melanopsis*, *Lymnocardium*, *Viviparus*, *Dreissena* etc.

STRATIGRAPHIC, PALEOECOLOGICAL AND TAPHONOMIC CHARACTERISTIC OF PALEOFAUNA

Stratigraphic remarks

The caspi-brackish late Upper Miocene is very well developed in Central Serbia, particularly in the vicinity of Belgrade. In papers by Serbian geologists it is usually determined as Lower and Upper Pontian. Although the strictly Pannonian and strictly Pontian species are commonly mixed together, the sediments younger than the Pannonian sediments of Vrčin near Belgrade (Karagača) are very easily distinguishable by the composition of mollusk paleofauna. These sediments abound in caspibrackish fauna, primarily composed of congeria, lymnocardiids and melanopsis.

The Upper Miocene sediments in the vicinity of Smederevo are best exposed along the bank of the Danube River. At Orešac there are several geological profiles (outcrops) characterized by the presence of almost identical paleofauna. Over twenty species of mollusks recorded at the studied localities were also recorded at other sites in the vicinity of Smederevo (Orešac I and Orešac II). Two families of bivalves are dominant: Dreissenidae and Lymnocardiidae. Dreissenidae were represented by genera *Mytilopsis* and *Dreissena.* The most abundant gastropods

were *Melanopsis decollata* Stoliczka. The family with the greatest number of species was Lymnocardiidae, represented by two genera, *Lymnocardium* and *Phyllocardium*. According to Stevanović (1951), the shallow-water sediments of Orešac were described as a Danube type of development, as they differ from the neighboring sediments of the Kolubara Basin in terms of the composition of the fauna and the type of sedimentation.

This fauna is characterized by a diversity of representatives of Lymnocardiidae and great individual variability in recorded species. Genus *Lymnocardium*, very diverse in Upper Pannonian, appears in large numbers in all studied sites. In contrast to limnocardiids, the number of species of Dreissenidae is very small. Many species of *Congeria*, otherwise very well distributed in Upper Miocene sediments of Serbia, are missing. The "Index" fossil *Congeria rhomboidea* Hörnes was not recorded in the study area. The closest locality with the subspecies *C. rhomboidea rhomboidea* Hörnes, described as a faciostratotype of Pontian stage and Portaferian substage, is Crveni Breg near Grocka (Stevanović 1990c). Only the subspecies *C. rhomboidea alata* Brusina was recorded at the Orešac II site (Stevanović 1951, Stevanović 1990d). The importance and role of the species *C. rhomboidea rhomboidea* Hörnes in the stratigraphy and paleogeography of Pannonian Lake was described by Gulyás, 2001. In contrast to *Congeria*, representatives of the genus *Dreissena,* which were generally very rare in Pannonian in Serbia, are represented by several species and a large number of individuals in sediments of Orešac.

Fauna of Orešac also includes representatives of Lower Pontian (*Lymnocardium apertum* Münster, *L. secans* (Fuchs), *L. vicinum* (Fuchs), *L. penslii* (Fuchs). *Mytilopis ungulacaprae* (Münster) from the Lower Pontian sediments of Serbia (Stevanović 1951) and Pannonian sediments of NW Hungary (Scilaj *et al.* 1999) were recorded in the sediments of Orešac only at the site of Brestovik near Grocka (Stevanović 1951).

Lymnaeidae were quite rare. *Radix* aff. *jaksici* (Brusina) was recorded in Pontian sediments of the Dacian basin (Romania) (Macaleț 2005). *Valenciennius* is not recorded at the sites of Orešac, while the deep-water species *Valenciennius reussi* was recorded at the neighboring localities (Kolubara, Mislođin).

The lymnocardids are fairly well represented in comparison to some other Pontian localities in Serbia (according to Stevanović 1951), while representatives of *Melanopsis* and *Congeria,* which reached an evolutionary boom in Pannonian, were lacking. The large types of Melanopsis were replaced by species with thinner shells (*Melanopsis decollata* Stoliczka, *M. sturii* Fuchs, *M. defensa* (Fuchs), where *M. decollata* was the most abundant. The large-shelled *Melanopsis* were represented by *M.*

petrovici Brusina. As a whole this is an endemic fauna. However, the percentage of endemic species is much lower than at the Orešac I and Orešac II sites, while freshwater forms were better represented.

Considering the composition of fauna, it may be assumed that the fauna of these localities is younger than the fauna of Beli Potok (Konopljište near Belgrade) which is described by Stevanović 1990b and the *Lymnocardium decorum zone* (Scilay *et al.* 1991). Fauna of Orešac is also reminiscent of fauna of Kozma St. (Budapest) (Magyar et. al. 2006), but does not contain any specimens of *Congeria praerhomboidea* Stevanović. According to the study of drill holes in the center of Beli Potok Trench (vicinity of Belgrade), Knežević (1990) determined that the older level of Pontian, according to Stevanović (1951), with a littoral type of development laterally transforms into the semi-basin type dominated by *C. praerhomboidea* Stevanović. At the center of Beli Potok Trench these layers are overlaid with layers of older Portaferian (according to Stevanović 1951), represented by alevrites and clays with *C. rhomboidea* Hörnes *Mytilopsis croatica* (Brusina), *M. zagrabiensis* (Brusina), *Lymnocardium zagrabiense* Brusina *L. majeri* Hörnes. In the sand-based intercalating layers there are also some *Dreissena auricularis* Fuchs. At this site the final Pontian layers are sand layers containing *Budmania histiophora* Brusina. The combination of these factors indicates that the Danube type of Groča-Smederevo Danube Area (according to Stevanović 1951) represents a specific facies of Portaferrian substage as defined by Stevanović. From the lithological standpoint, this facies is dominated by small-grained sands with cited fauna. Clay layers are less common and may infrequently include specimens of Congeria rhomboidea rhomboidea Hörnes (Stevanović 1951). Fauna of Beli Potok (Konopljište) has many species in common with fauna of Orešac, but actually represents a level of Pontian with a littoral type of development, with fauna containing a much greater number of Pannonian forms: *Mytilopsis trnskii* Brusina, *M. vuki* Brusina, *M. ungulacaprae* Münster etc. The exclusively Pannonian species used to determine Pannonian from Pontian are missing (Stevanović 1951, 1977): *Mytilopsis czjzeki czjzeki* Hörnes, *Congeria parstchi partschi* Czjzek etc.

In comparison with the Pontian sediments of the western part of the Dacian basin, the similarities in paleofauna are minimal. According to Stevanović (1951, 1977) and Jovanović & Jovanović (1998) Pontian in Eastern Serbia was developed at Ključ (near Kladovo und Negotin in Northeastern Serbia) with numerous recorded species from Pannonian and Euxinian Pontian. This locality is situated at one of the main migration pathways of Pontian fauna between the western and the eastern part of Paratethys. Lymnocardiidae, Dreissenidae and Lymnaeidae were for the

most part derived directly (or indirectly through the earliest Pontian ancestors) from the Pannonian forms (Stevanović 1990a). The endemic mollusks of the Pannonian Lake flourished and migrated probably episodically into the Eastern Paratethys during the Pontian era, via the outflow of the lake (Stevanović 1990d; Müller *et al.* 1999, Popov *et al.* 2006). Macaleț (2003-2004) cites several species: *Lymnocardium zagrabiense* Brusina, *Paradacna abichi* Hornes, *Dreissena serbica oresacensis* Stevanović, in the Middle Pontian (Portaferrian) of the Cislău Area. According to Stevanović (1951), the facies of Upper Pontian sediments at the western edge of the Dacian Basin (Eastern Serbia), given its faunistic feature, represents a traditional type between the Pannonian facies in the west and "Ponto-caspian" in the east (the eastern Paratethys). This type of migration of fauna was also explained by some other authors (Marinescu 1978, Jipa & Olariu 2009). The first forms that inhabited the surface of the western part of the Dacian Basin were the immigrant forms from the Pannonian Basin (Marinescu 1978) (Jipa & Olariu 2009). A good example is *Paradacna abichi* Hornes, which quickly spread throughout the Dacian and Euxinian regions. This species used to inhabit areas of Western Serbia during the Pontian stage (Stevanović 1951), and in Eastern Serbia it appears in the Portaferian substage.

Sediments of Late Miocene (Pannonian) from the vicinity of Grocka are very different in faunistic composition from the younger sediments assigned to Pontian (Stevanović 1951; Knežević 1994). The fauna identified in the studied area matches the Upper Miocene (according to Magyar 1999a), Upper Pontian-Portaferrian (according to Stevanović 1951) and the highest level of the last phase of lacustrine Pannonian, Phase III(8.0-5.8 Ma) (according to Harzhauser and Mandić 2008).

Paleoecological remarks

Bivalves were better represented than gastropods at all sites of Orešac, not only in terms of the number of species but also the number of individual specimens, except at the site Udovički potok (Jovanović 1988). The diversity of fauna and mass appearance of specimens of the same species indicate that living conditions in the lacustrine environment were quite favorable. As a whole, fauna is still endemic, but the percentage of endemic species is much smaller than at the localities of Orešac I and Orešac II. Concerning salinity, the fauna is represented by brackish and freshwater species. *Mytilopsis* is a euryhaline form, in contrast to *Dreissena* which inhabit fresh water of lakes and rivers (Harzhauser & Mandić 2004). According to Korpás Hódi (1983) a similar association of mollusks used to

inhabit the sublittoral of the lake shores, at a depth of about 80 *m*. The Pannonian and Pontian mollusk fauna inhabited the miohaline environment with salinity levels of up to 16 ‰ (Stevanović 1990a). Estimates of salinity were made according to mollusk and ostracod fauna. Many authors believe that in the last phase in the development of the Pannonian Lake salinity was around 0.5 psu (Harzhauser *et al.* 2007). Sands of Orešac were described as beach formations, brought by the river, altered by wave and current activity, and deposited at the lake bed (Krstić *et al.* 1992).

The lymnaeid *Valenciennius,* which is a large gastropod, was not recorded as it was a form characteristic of deep water. Other prominent forms with large strong shells include *Mytilopsis triangularis* Partsch, *Melanopsis petrovici* Brusina. The pronounced presence of species with large thick shells indicates a very warm, shallow and mobile water environment with plenty of detritus and calcium carbonate necessary for shell formation. It seems that there was no drastic decrease of oxygen, as the presence of most mollusk species at all studied localities was continuous.

The accumulation of shells in thin intercalating layers, sometimes forming coquinas (Fig. 3, 5), indicates a local character of changes in the sedimentation basin. Coquina from the outcrop Orešac-Udovice was recorded in a thin layer, about 15 *cm* thick (Fig 3). Unfortunately this thin lens-like layer is now eroded. Coquina (Fig. 5) from the outcrop Orešac--Udovice (New road to Požarevac) (Fig. 4) is composed of numerous well--preserved mollusk shells and shell fragments worn by wave activity, and may indicate water environment with decreased influx of sediments. In certain places there was some sorting of material, indicated by lumacelle formed from numerous shells of *Melanopsis decollata* Stoliczka. Fauna at this locality is quite poor in number of species but very rich in number of individuals. Together with the presence of species with thicker, larger shells this indicates close proximity to coastline.

Among the filter-feeding representatives of epifauna the most important forms are *Dreissena* and *Mytilopsis*. According to Nuttall (1990), all known recent species of *Dreissena* belong to epifauna. As typical bissate epibionts they form colonies attached to some object or to each other. Dreisseninae originated during the Eocene age, probably from brackish Corbiculidae. Congeria is an endemic genus from Paratethys, originating at Pannonian Lake (Nuttall 1990; Harzhauser & Mandić 2004). Representative of infauna (*Dreissenomya*) was recorded only at Orešac II (Stevanović 1951). Limnocardiids are very active organisms that create shallow hollows in sediment. The presence of pulmonate gastropods and prosobranchia, as well as other fauna, indicates a shallow and mobile lacustrine environment with favo-

rable living conditions (littoral and sublittoral). The presence of large smooth *Viviparus* and other exclusively freshwater formsindicates the increased influence of the mainland through influx of fresh water, indicating that the salinity of the water environment at the time when sediments were deposited was decreased, not only when compared to older neighboring parts of the basin in the Upper Miocene of Serbia but also to contemporary ones. A mass occurrence of the species *Viviparus sadleri* Partsch is cited for areas further east toward Smederevo (Stevanović 1951).

At the locality of Smederevo (Provalije) layers of sands and clays alternate with layers of coal (Filipović 1962 etc.). The clays had contained freshwater forms: *Planorbis sp., Lymnophysa sp*., *Lymnaea sp*. The appearance of several layers of lignite and an increase in their number from West to East indicates the presence of occasional periods of an alternating warm humid climate and arid conditions in the Danube area (Anđelković *et al.* 1989). Certain authors believe that the occurrence of *Hipparion* near Grocka, in sediments with Upper Pontian mollusks, indicates sporadic events of coastline modification and strong influx of fresh water (Stevanović and Pavlović 1969).

Fish fauna of the Orešac locality includes both marine and freshwater representatives. The otolites belong to adult and juvenile individuals of the families Sciaenidae and Gadidae. Members of the family Sciaenidae live in both fresh and saltwater basins in temperate and tropical regions, mostly in the estuaries and bays. Adults of modern *Umbrina cirrosa* inhabit coastal marine waters in the East Atlantic, Mediterranean Sea, Black Sea, and Sea of Azov, and their juveniles enter the estuaries (Cziczer *et al.* 2009). *"Genus Gadidarum" ponticum* belongs to the family of typical marine fish (fam. Gadidae). The clearly freshwater family Cyprinidae is presented by *Barbus* sp. The fish fauna is a mostly marine relict adapted to brackish and freshwater conditions interspersed with freshwater inhabitants.

Taphonomic characteristics

Alternations of sediments are not common at the studied sites. All layers contain a well-developed mollusk fauna, usually uniformly distributed. In the sandy layers there was no visible sorting of shells or any other type of orientation that could indicate longer transport. A record of a *Hipparion* skull may be explained by its transportation into the shallow lacustrine environment by river activity.

Considering the state of preservation of material, it may be concluded that the specimens were excellently preserved. Besides the large forms there are also some well-preserved specimens with very fragile and thin,

brittle shells, especially among bivalves. The recorded damage originated mostly during and after sedimentation and is mechanical in nature, indicating an autochthonous character of oryctocenosis. The presence of shells of different ages also indicates that fauna was found "*in situ*". Best preserved species were those with thicker shells, adapted to life close to the coastline: *Viviparus sadleri* Partsch, *Lyrcaea petrovici* (Brusina), *Phyllocardium complanatum* (Fuchs), *Valvata variabilis* Fuchs, and *Melanopsis decollata* Stoliczka. *M. sturii*, as a direct descendant of *M. bouei*, was reported by Korpás-Hódi 1983 (Harzhauser *et al.* 2007) from lagoon-like, partly swamp-like, quiet-water facies, indicating oligohaline to freshwater conditions. It is believed that the genus *Phyllocardium* with its flattened but very strong shell prefers the wave-breaking zone (Diaconu 2006).

The studied localities were characterized by pronounced diversity in representatives of Lymnocardiidae and large individual variability of certain species (*Lymnocardium diprosopum*, *Dreissena auricularis auricularis*). Among the congerias, the best represented species was *Mytilopsis triangularis* Partsch, and of the *Dreissena* species there is a mass appearance of *Dreissena auricularis auricularis* Fuchs. *Dreissena* specimens show a pronounced variability of shells. Bach (1993) tried to explain the variability of *Dreissena* on specimens from Croatia. In contrast to congerias, the genus *Lymnocardium*, very diverse in Upper Pannonian, appears in large numbers in all studied localities.

CONCLUSION

The Upper Miocene sediments of Serbia are characterized by a well--developed facies diversity and excellently preserved malacofauna, as shown in the example of the sediments in the vicinity of Smederevo. Previous studies have shown that, even though some localities are long gone, there are still other fossil-rich sites characteristic of Upper Miocene, representing an inevitable segment in the stratigraphic determination and correlation of Neogene sediments. Due to the importance and richness of mollusk paleofauna, the localities of Orešac have been visited during several national and international expert field trips.

This paper includes descriptions of the geological localities Sastavci, Orešac-Udovice and Orešac-Udovice (New road to Požarevac) with lists of collected species. Review was performed on fossil remains of fish (teeth and otolites). The locality Sastavci represents a direct continuation of sediments from the locality described as faciostratotype Orešac I (Steva-

nović 1951), which is not preserved today. The fauna mostly originated in caspi-brackish waters, while there were some freshwater species as well. In the west-east direction, toward Smederevo, the first mass appearance of the species *Viviparus sadleri* Partsch and *Viviparus viminaticus* Brusina was recorded at the profile Orešac-Udovice (New road to Požarevac), so it may be assumed that they belong to the highest part of the Groča-Smederevo Danube type of development in Upper Miocene.

The main stratigraphic, paleoecological and taphonomic characteristics of paleofauna were determined after the analysis of the collected material. In contrast to other synchronous sediments, it may be concluded that the studied area is rich in representatives of fauna recorded in older sediments of Upper Miocene, but in much smaller numbers than in profiles Orešac I and Orešac II etc. The more precise stratigraphic and paleoecological characteristics will be determined by using more modern methods in future studies.

As the questions pertaining to solving the issues of Upper Miocene of Paratethys and Neogene of Serbia (very well developed in this region and very rich in representation of fossil species) are discussed even today, the studied localities may contribute to better knowledge of the geology of the vicinity of Smederevo. As the determination of boundaries between Pannonian and Pontian was mostly based on the families Lymnocardiidae and Dreissenidae which are very common in the sediments of Orešac, the described localities and collected fauna may also contribute to better knowledge of the development of the Upper Miocene. Besides the historical importance for the paleontological and stratigraphic science of the broader region, the described localities are also a particularly important part of its geoheritage, and not only that of Serbia.

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ГОРЊЕМИОЦЕНСКА ФАУНА ОРЕШЦА КОД СМЕДЕРЕВА (СРБИЈА)

ГОРДАНА ЈОВАНОВИЋ, СЛОБОДАН КНЕЖЕВИЋ, ДРАГАНА ЂУРИЋ,
MARIANN BOSNAKOFF, ГОРДАНА ПАУНОВИЋ

Р Е З И М Е

Горњемиоценски седименти Србије одликују се израженом фацијалном разноврсношћу и садрже добро очувану малакофауну о чему сведоче и седименти, откривени у околини Смедерева. На основу досадашњих истраживања утврђено је да поједини локалитети више не постоје, али су откривена друга фосилоносна налазишта, значајна за стратиграфска рашчлањавања и корелацију неогених седимената.

У раду су описани геолошки локалитети Саставци, Орешац-Удовице и Орешац-Удовице (нови пут за Пожаревац), дати су спискови сакупљених врста и извршена је ревизија фосилизованих остатака риба (зуби и отолити) из збирке Природњачког музеја. Седименти откривени на локалитету Саставци представљају директан продужетак седимената локалитета Орешац I, описаног као фациостратотип (Stevanović 1951), који није сачуван. Фауна је углавном каспибракична, али су констатовани и маринске представници, углавном из фамилије *Lymnocardiidae.* Будући да је прво масовно појављивање представника врста *Viviparus sadleri* Partsch и *Viviparus viminaticus* Brusina, запажено на профилу Орешац-Удовице (нови пут за Пожаревац), претпоставља се да је старост седимената са фауном синхрона са највишим делом

„подунавског типа" развића горњег миоцена у грочанско-смедеревском Подунављу.

На основу сакупљеног материјала приказане су основне палеоеколошке и тафономске карактеристике палеофауне. Будућа истраживања усмериће се на прецизнију одредбу старости и на детаљнија палеоеколошка проучавања. С обзиром на чињеницу да је до сада уврдјивање границе између панона и понта вршено најчешће на основу представника из фамилија *Lymnocardiidae* и *Dreissenidae*, мишљења смо да фауна, сакупљена на локалитетима Саставци, Орешац-Удовице и Орешац-Удовице (нови пут за Пожаревац) може допринети бољем познавању развића понта на овим просторима. Због значаја за развој палеонтологије и стратиграфије ширег региона, описани локалитети не представљају само објекте геонаслеђа Србије.

Plate I

1. *Lymnocardium penslii* (Fuchs), Sastavci.
2. *L. decorum* Fuchs, Sastavci.
3. *L. diprosopum* (Brusina), Sastavci.
4. *Phyllocardium complanatum* Fuchs, Orešac-Udovice (New Road to Požarevac).
5. *L. zujovici* Brusina, Sastavci.

6a,b. *Mytilopsis triangularis* (Partsch), Orešac-Udovice (New Road to Požarevac).

7. *Lymnocardium* cf. *diprosopum* (Brusina), Orešac-Udovice (Udovički potok).
8. *Dreissena auricularis auricularis* Fuchs, Orešac-Udovice (New Road to Požarevac).
9. *Lymnocardium sp*. Orešac-Udovice (Udovički potok).
10. *L.* cf. *scabriusculum* Fuchs, Sastavci.

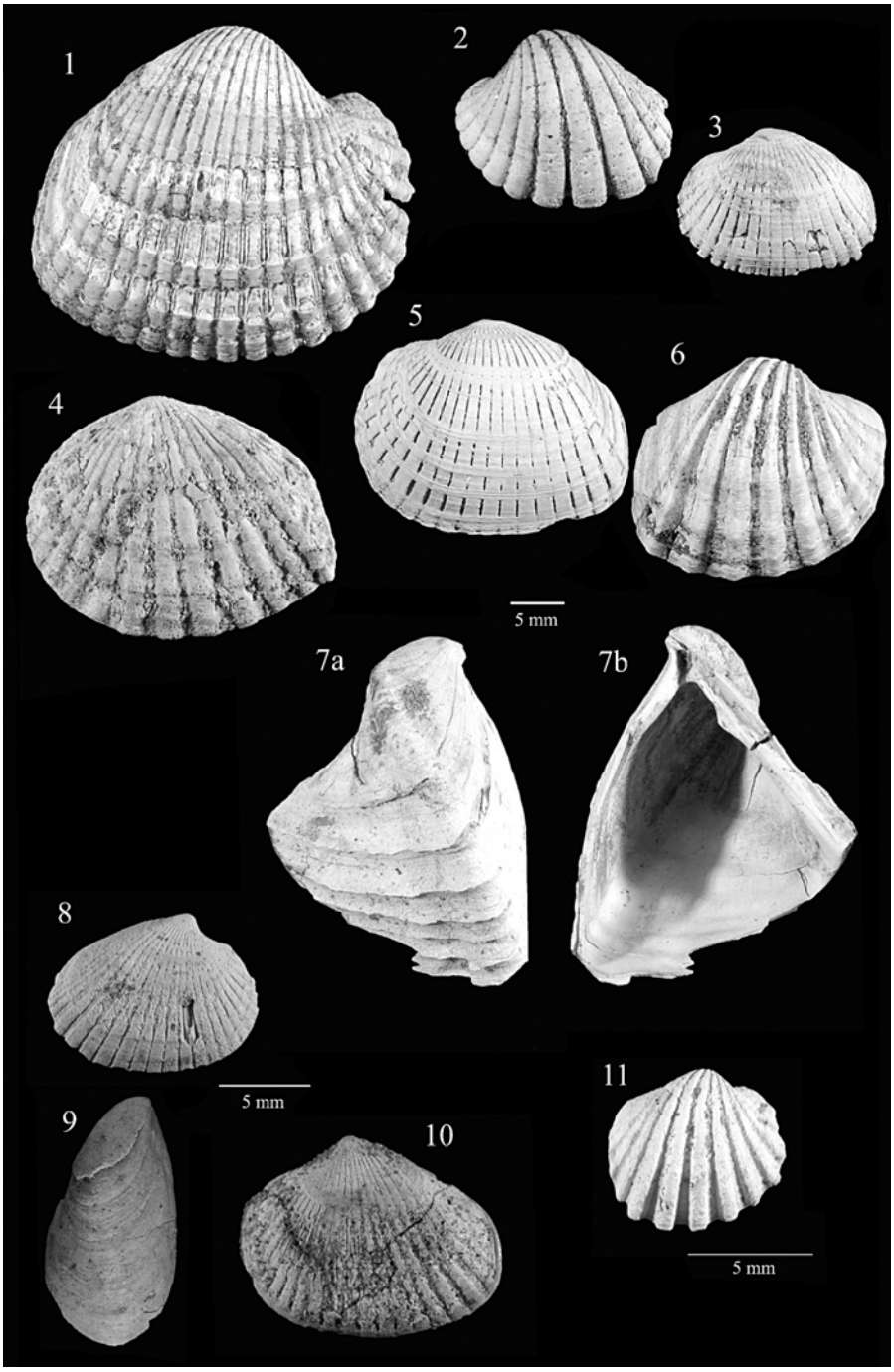
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Plate II

1. *Trewasciaena kokeni* (Schubert), Orešac-Udovice (Udovički potok).
2. *Trewasciaena kokeni* (Schubert), Sastavci.
3. *Umbrina cirrhosoides* (Schubert), Sastavci.
4. fam. *Sciaenidae* – zub/tooth, Sastavci.
5. *"Genus Gadidarum" ponticum* (Weinfurter), Sastavci.
6. fam. *Cyprinidae* – zub /tooth (*Barbus sp*.), Sastavci.
7. *Valvata variabilis* Fuchs, Orešac-Udovice (New Road to Požarevac).
8. *Micromelania klaici* Brusina, (New Road to Požarevac).

9a,b. *Melanopsis sturii* Fuchs, Sastavci.

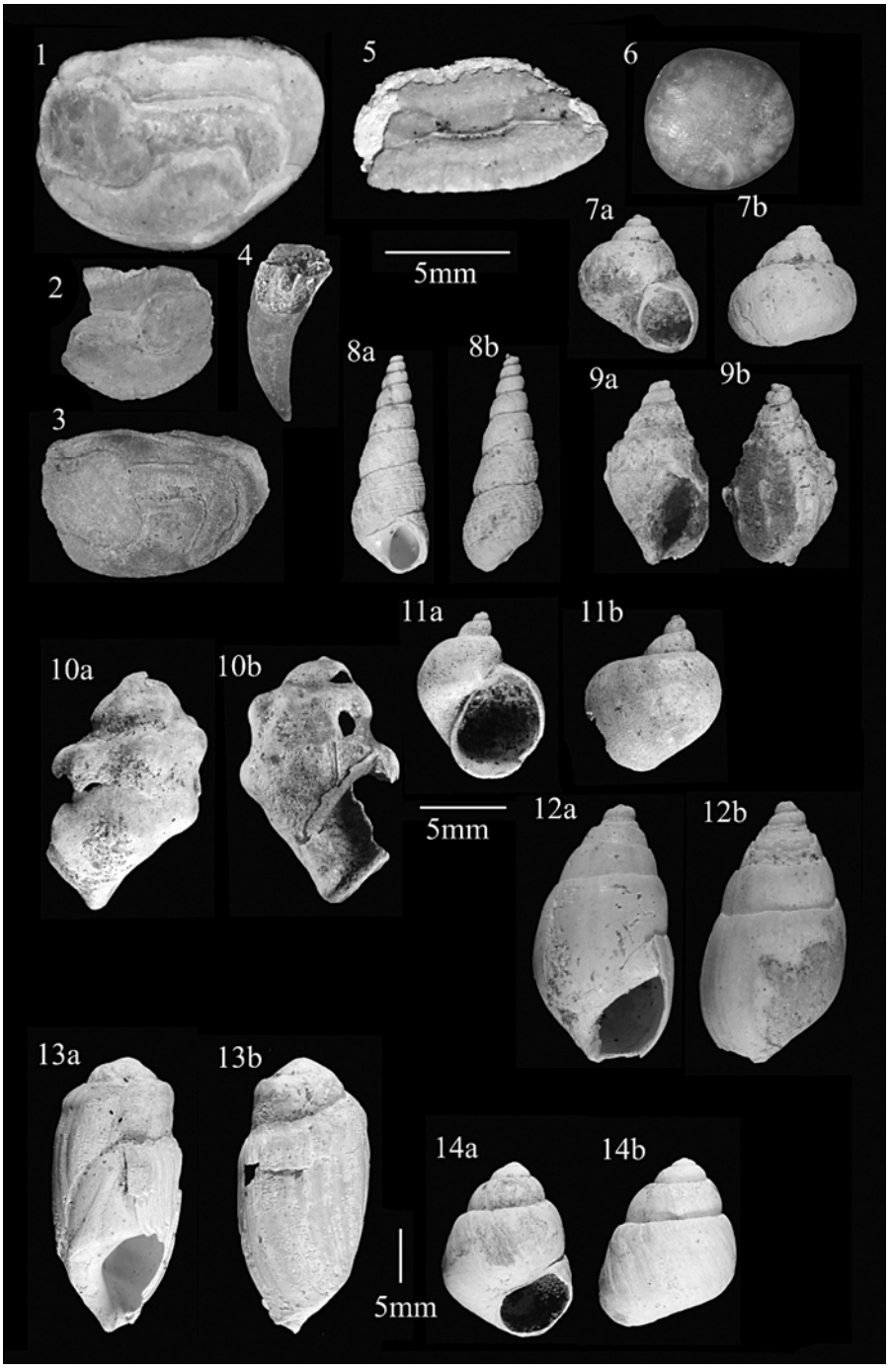
10a,b. *Melanopsis defensa* Fuchs, Orešac-Udovice (New Road to Požarevac).

11a,b. *Radix jaksici* (Brusina) Orešac,-Udovice (New Road to Požarevac).

12a,b. *Melanopsis decollata* Stoliczka, Orešac-Udovice (New Road to Požarevac).

13a,b. *Melanopsis petrovic*i Brusina, Orešac-Udovice (New Road to Požarevac).

14a,b. *Viviparus sadleri* Partsch, Orešac-Udovice (New Road to Požarevac).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