

## The First evidence of marine Badenian transgression near Koceljeva (Central Paratethys, western Serbia)

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### Key words:

*Central Paratethys, calcareous nannoplankton, foraminifers, mollusks, Koceljeva, lower Badenian.*

**Abstract.** This paper presents the first detailed biostratigraphic investigation of deposits cropping out in stream Sumijevac near Koceljeva (western Serbia). The most important fossil communities and their significance are presented. New biostratigraphic results have been achieved by the study of calcareous nannoplankton, foraminifera and mollusks fauna which clearly indicate the presence of the lower Badenian zone (Lagenid Zone), and defines precisely time of the marine transgression in this area. Further, the revised age of the sedimentary deposits presented here provides the necessary background information for future research of the Badenian sediments of Serbia and neighbouring regions.

### Кључне речи:

*Централни Паратетис, кречњачки нанопланктон, фораминифери, мекушци, Коцелјева, доњи баден.*

**Апстракт.** Овај рад представља резултате првих детаљних биостратиграфских истраживања седимената из профила откривеног у потоку Сумијевац код Коцелеве (западна Србија). Приказане су најважније заједнице фосила и њихов значај. Нови биостратиграфски резултати добијени проучавањем кречњачког нанопланктона, фораминифера и фауне мекушаца јасно указују на присуство доњобаденске зоне (лагенидна зона), и прецизно дефинишу време морске трансгресије у овој области. Поред тога, ревидирана старост седимената пружа основне потребне информације за будућа истраживања баденских седимената Србије и суседних региона.

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## Introduction

During the middle Miocene (Badenian) the wider area of Koceljeva (western Serbia), were situated to the southern margin of the Pannonian Basin System. The fossiliferous deposits at Koceljeva vicinity developed during middle Miocene transgression in the northern slopes of Bukulja Mountain. Locality is situated about 1 km southwest of Koceljeva (Fig. 1b). The wider area of Koceljeva and its fossils fauna were the subject of investigation by STEVANOVIĆ (1959), STEVANOVIĆ & MILOŠEVIĆ (1959), EREMIJA, (1977), DOLIĆ & KRSTIĆ (1985), followed by publishing a lists of fossils. More than 100 species of mollusks have been identified. The stratigraphical position of the Sumijevac (Sumnjivac) stream deposits was based primarily on the foraminifera (GAGIĆ, 1968; PETROVIĆ, 1985), while all previous investigations yielded different stratigraphic attributions (STEVANOVIĆ, 1959; GAGIĆ, 1968; EREMIJA, 1977; PETROVIĆ, 1985; EREMIJA & PAVLOVIĆ, 1990; JOVANOVIĆ, 2018). In order to resolve the difficulties involved with age determination of the fossiliferous beds exposed at the locality Sumijevac, here we present the results of investigations of foraminifera, calcareous nannofossil and mollusks assemblages performed on three samples taken from this locality. The well exposed section consists of five layers, whereas lowermost and uppermost parts of the described outcrop have not been investigated due to the lack of fossils. Sediments cropping out in the Sumijevac section contain a large number of fossils, especially mollusks. Preservation is fairly good all through the section.

The aim of this paper is to present results of investigations carried out in the Badenian deposits exposed at the locality Sumijevac.

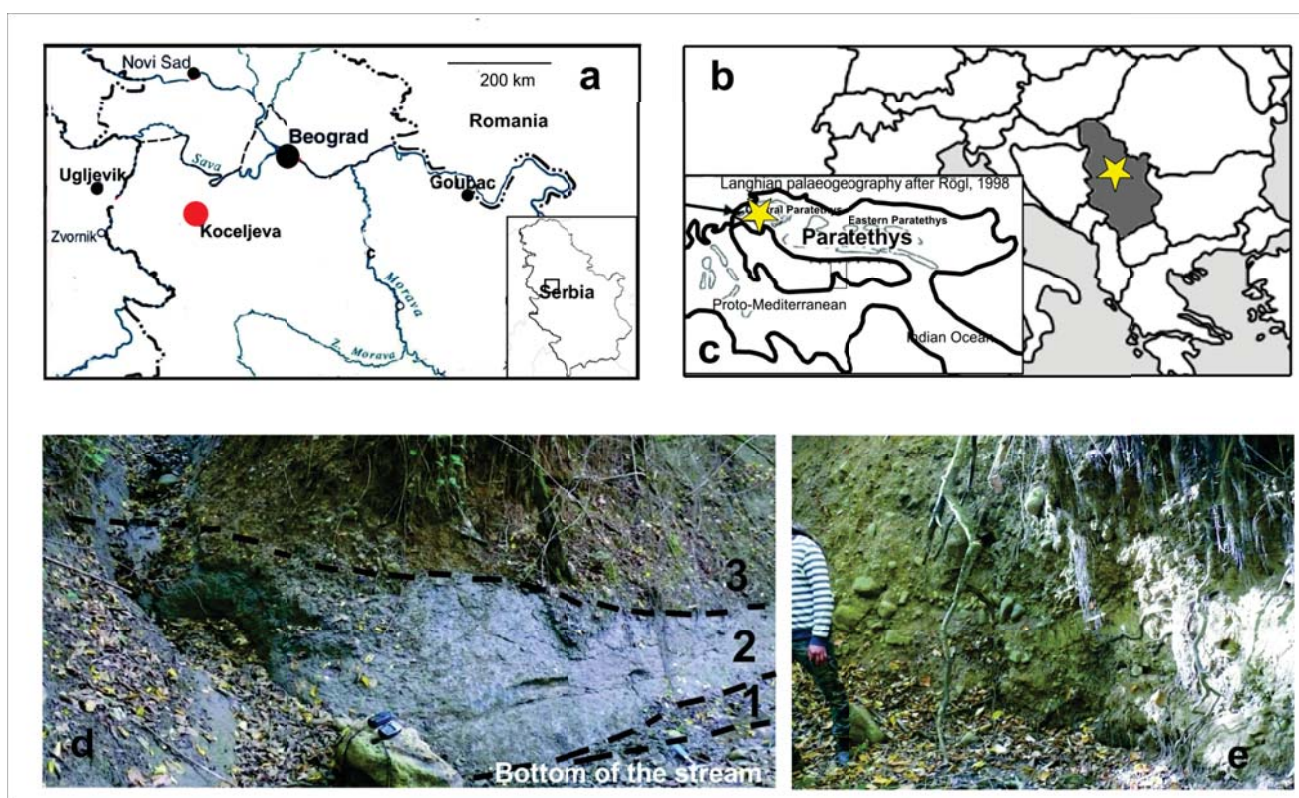
## Geological setting

During the middle Miocene, the Paratethys flooded different types of basement in Serbia and a normal marine regime developed in the area (ANĐELKOVIĆ et al., 1989), as a result of the increase in global sea level (KOVAČ et al., 2007). The locality Sumijevac provides valuable geological and paleontological data of Koceljeva area palaeoenvironments in western Ser-

bia during the early-middle Miocene. Similar lower Badenian deposits recently were described in Bosnia (ĆORIĆ et al., 2018). Well-documented Badenian lithostratigraphic units are recognized in several basins such as: Podrinje, Kolubara, Belgrade and Velika Morava (ANĐELKOVIĆ et al., 1989). In the vicinity of Koceljeva (Kolubara basin), fossiliferous beds are exposed in the valley of Sumijevac Stream. Palaeogeographically, this site is located at the extreme southern margin of the Pannonian Basin, and belongs to the Koceljeva Graben that occupies the extreme southwestern part of the Kolubara-Tamnava Basin, constricted between the horsts of Vlašić-Bližonj in the south and Jazovnik in the north (after MAROVIĆ et al., 2007). Sedimentary rocks in the outcrop are represented by polimicrite conglomerates and sandstones. Badenian deposits of the wider area of Sumijevac Stream are rich in fossil records (STEVANOVIĆ, 1959). However, the palaeontological investigations have not taken place in the area regularly over the last decades, because sediments are only exposed on the banks of the stream and can be seen only at a low water level. GAGIĆ (1968) and PETROVIĆ (1985) investigated foraminifers from this locality and attributed these deposits to the late Badenian. They were generally related to the synrift phase of the Pannonian Basin (MAROVIĆ et al., 2007). This locality is situated at the Basic Geological Map 1:100,000, sheet Vladimirci L 34-124 (FILIPOVIĆ et al., 1973). Koceljeva graben was filled with deposits from the lower Miocene to the upper Miocene. We investigated about 2.8 m thick transgressive middle Miocene (Badenian) deposits (Fig. 1d) which unconformably overlies the lower Miocene freshwater sediments (STEVANOVIĆ 1977).

## Material and methods

Middle Miocene (Badenian) deposits of the Koceljeva contain diverse fauna and often have exceptional fossil preservation. Also, fossil material of the Sumijevac Stream is very well preserved and only several specimens show signs of reworking. Research methods have included field work and laboratory investigation in the Natural History Museum of Belgrade (Serbia), Geological Survey of Austria and University of Tuzla, Faculty of Mining, Geology



**Fig. 1.** *a.* Geographical position of Sumijevec locality in Europe; *b.* Location of the studied area in Serbia; *c.* Langhian palaeogeography (after Rögl, 1998) showing the location of the studied succession (yellow star); *d.* Photo of studied section with indication of the sampled beds: 1 (conglomerates); 2, 3 (sandstones); *e.* Photo of basal conglomerates.

and Civil Engineering (Bosnia and Herzegovina). Field work and sampling at this locality was conducted during 2017. The procedures adopted for the fossil extraction are in accordance with standard palaeontological sample preparation technique. For the microfossil extraction, three samples were prepared and washed at the laboratory and allowed to dry. Laboratory methods were employed for disintegrating soft sandstone using hydrogen peroxide. After that water is added and allowed to stand for few hours. Samples were washed over a 0.1 mm-sieve and picked under the microscope. The specimens were identified with age attribution.

Small amounts of sediments were taken for the calcareous nannofossils investigation. Smear slides were prepared following the standard procedure described by PERCH-NIELSEN (1985). The stratigraphical analysis of the nannoplankton zonation is followed by MARTINI (1971), while the foraminifera zonation is based by GRILL (1943).

We recognized five layers, but lowermost and uppermost parts of the described outcrop have not been investigated. For this research, the authors have chosen only beds rich in fossil remains. All collected material is stored in the collections of Natural History Museum in Belgrade (Serbia). The part of studied specimens of foraminifera are housed in the University of Tuzla, (Bosnia and Herzegovina), while the samples of nannoplankton assemblages are stored in the collection of the Geological Survey of Austria in Vienna.

### Biostratigraphy

Biostratigraphic analysis is based on the part of this section with three lithological units recognized and described from the bottom to the top in Figs. 1 and 2. The studied part of the outcrop starts with a fine-grained, weakly cemented polymictic conglomerate (sample 1). Angular and slightly rounded quartz

grains which are sometimes transparent and glossy dominate. The grains of quartz, limestone and others rocks are slightly rounded, up to 1 cm in size. Grains of mica are very rarely represented. Besides calcareous nannoplankton and foraminifera the conglomerate contains abundant good preserved shells of juvenile mollusks, fragments of some adult mollusks, disarticulate shells of adult bivalves, echinoid spines, ostracods and otolites. This unit is about 0.5 m thick.

Calcareous nannoplankton is rare, but well preserved and contains *Sphenolithus heteromorphus* DEFLANDRE, 1953. Nannoplankton assemblage is characterised by the domination of *Reticulofenestra minuta* ROTH, 1970, *Coccolithus pelagicus* (WALLICH, 1877); SCHILLER, 1930, *Braarudosphaera bigelowii* (GRAN & BRAARUD, 1935) DEFLANDRE, 1947, *Coronocyclus nitescens* (KAMPTNER, 1963) BRAMLETTE & WILCOXON, 1967, *Helicosphaera carteri* (WALLICH, 1877), KAMPTNER, 1954, *Helicosphaera mediterranea* MÜLLER, 1981, *Rhabdosphaera sicca* (STRADNER, 1963) FUCHS & STRADNER, 1977, *Sphenolithus heteromorphus* DEFLANDRE, 1953, *Sphenolithus moriformis* (BRONNIMANN & STRADNER, 1960) BRAMLETTE & WILCOXON, 1967, *Thoracosphaera saxea* STRADNER, 1961. Also, rare reworked Upper Cretaceous species *Eiffelithus gorkae* REINHARDT, 1965, *Micula staurophora* (GARDET, 1955) STRADNER, 1963 and *Watznaueria barnesiae* (BLACK & BARNES, 1959) PERCH-NIELSEN, 1968 were observed.

Foraminifers are very rare and represented almost exclusively by benthic forms. Only single specimen of *Trilobatus* presents planktic form. Assemblage is dominated by *Ammonia*, *Asterigerinata*, *Elphidium* and Miliolidae. *Ammonia viennensis* (d'ORBIGNY, 1846), *Nonion commune* (d'ORBIGNY, 1846), *Asterigerinata planorbis* (d'ORBIGNY, 1846), *Trilobatus trilobus* (REUSS, 1859), *Borelis melo melo* (FICHTEL & MOLL, 1798), *Porosonion granosum* (d'ORBIGNY, 1846), *Dendritina haueri* d'ORBIGNY 1846, *Lenticulina inornata* (d'ORBIGNY, 1846), *Cibicidoides ungerianus ungerianus* (d'ORBIGNY, 1846), *Spirolina austriaca* d'ORBIGNY, 1846, *Anomalinoidea badenensis* (d'ORBIGNY, 1846), *Elphidium crispum* (LINNEUS, 1758), *Elphidium rugosum* (d'ORBIGNY, 1846), *Bolivina* sp., *Triloculina* sp. and *Quinqueloculina* sp. were determined.

The polymictic conglomerate is rich in fossils and contains a good preserved shells of juvenil mollusks and fragmented shells of adult individuals. Among

the mollusks juvenile forms, *Corbula gibba* (OLIVI, 1792) is quite common. Poorly preserved specimens and fragments of *Azorinus* cf. *chamasolen* (da COSTA, 1778), *Venus nux* GMELLIN 1791, *Turritella badensis* SACCO, 1895, *Calyptraea chinensis* LINNAEUS, 1758, *Polinices* sp., *Conus* sp. are also recognized.

The conglomerate is overlain by a layer of grey, poorly cemented sandstone (sample two) with similar association of nannofossils and foraminifera and much more diverse and better preserved mollusks specimens. Angular and weakly rounded quartz and calcite grains, as well as fragments of mica are detected under the microscope. In common with conglomerate layer, the nannoplankton association is the same. The benthic foraminifera are dominant, whereas planktic forms are represented by the genus *Globorotalia*. The following species were determined: *Ammonia viennensis* (d'ORBIGNY, 1846), *Nonion commune* (d'ORBIGNY, 1846), *Lenticulina clypeiformis* (d'ORBIGNY, 1846), *Elphidium crispum* (LINNAEUS, 1758), *Quinqueloculina buchiana* d'ORBIGNY, 1846, *Asterigerinata planorbis* (d'ORBIGNY, 1846), *Borelis melo melo* (FICHTEL & MOLL, 1798), *Bolivina antiqua* d'ORBIGNY, 1846, *Porosonion granosum* (d'ORBIGNY, 1846), *Globorotalia* sp. These deposits contain mollusk-dominated accumulations with numerous specimens of different oriented bivalves and gastropods. The molluscan association is diverse and represented by juvenile and adult forms: *Tellina planata* (LINNAEUS, 1758), *Seila trilineata* (PHILLIPI, 1836), *Corbula gibba* (OLIVI, 1792), *Nucula placentina*, LAMARCK, 1819, *Cardites partschi* (MÜNSTER IN GOLDFUSS, 1840), *Venus nux* GMELLIN, 1791, *Teinostoma woodi*, (HORNES, 1855), *Caecum trachea* (MONTAGU, 1803), *Turritella badensis* SACCO, 1895, *Turritella tricineta* BORSON, 1821, *Turritella* sp., *Granulifera hoernesii* (DODERLEIN, 1862), *Polinices* sp., and pteropod *Vaginella austriaca* KITTL, 1886. The second lithological unit attains a thickness of about 1 m.

The third layer at the top of the succession is composed of grey, whitish to yellowish, very fine-grained, poorly cemented sandstone. Microscopically, the pronounced dominance of quartz grains, with significantly subordinate participation of calcite grains and fragments of mica minerals is observed. These sediments are richer in the calcareous nannoplankton content than previous ones and contain also *S. heteromorphus*. The list of identified species

is identical to those from the lower bed, while *Reticulofenestra minuta* dominates by more than 90% in the total assemblage. The foraminifera fauna is relatively rare and represented only by benthic forms: *Ammonia viennensis* (d'ORBIGNY, 1846), *Nonion commune* (d'ORBIGNY), *Asterigerinata planorbis* (d'ORBIGNY, 1846), *Textularia* sp., *Textularia gramen gramen* d'ORBIGNY, 1846, *Bolivina* sp., *Bolivina antiqua* d'ORBIGNY, 1846, *Heterolepa dutemplei* (d'ORBIGNY, 1846), *Reussella spinulosa* (REUSS, 1850), *Elphidium* sp. and *Pseudotriloculina consobrina* (d'ORBIGNY). New forms of mollusks with large shells such as *Atrina pectinata* (LINNAEUS, 1767) (in situ) and *Procardium danubianum* MAYER, 1866 appear here, associated by: *Semicassis laevigata* DEFRANCE, 1817, *Azorinus chamasolen* (da Costa, 1778), *Cubitostrea digitalina* EICHWALD, 1830, *Cardites partschi* MÜNSTER IN GOLDFUSS, 1840, *Turritella badensis* Sacco, 1895, *Turritella* sp., *Strioterebrum* (*Strioterebrum*) *bistriatum* (GRATELOUP, 1833), *Strioterebrum basteroti* (NYST, 1843), *Tellina planata* (LINNAEUS, 1758), *Terebra neglecta* (MICHELOTTI, 1847), *Phasmoconus fuscocingulatus*, (HORNES, 1851), *Kalloconus berghausi* MICHELOTTI, 1847, *Nati-*

*carius stercusmuscarum* (GMELLIN, 1791) etc. The third unit is about 1.30 m thick.

The identification of the nannoplankton zone NN5 (MARTINI, 1971), (Fig. 3), was made based on the presence of *Sphenolithus heteromorphus* and the absence of *Helicosphaera ampliaperta* in all investigated samples. The last occurrence of *H. ampliaperta* defines the NN4/NN5 boundary. Planktic foraminifera are very rare in the Sumijevac deposits, making correlation with the planktic zonation difficult. Therefore, biostratigraphic zonation is mainly based on the benthic foraminifera which have relatively high diversity in the study section. The associations of foraminifers from the analysed samples also indicate that the sedimentary deposits of Sumijevac belong to the *Ammonia viennensis* and *Nonion commune* zone of the early Badenian. The zone is dated as middle Miocene based on the presence of benthic forms, and corresponds to the M5 zone of BERGGREN et al. (1995), on the regional scale (Paratethys). Also, the characteristic species *Lenticulina clypeiformis* found only in the lower Badenian of Central Paratethys (CICHA et al., 1998) was discovered in the sample No. 2 (bed 2). In

addition, *Ammonia* with quite large shell is a characteristic form of lower Badenian (PAPP & SCHMID, 1985; VRABAC, 1989). The presence of the holoplankton species *Vaginella austriaca* indicates the lower Badenian age of these sediments. This pteropod is rare or absent in the deposits of western and central Serbia (STEVANOVIĆ, 1970). PEZELJ et al. (2013) reported the occurrence of *V. austriaca* in the lower Badenian sediments (Upper Lagenidae zone) of Ugljevik (Bosnia and Herzegovina).

## Discussion and Interpretation

In this paper, the Badenian marine sediments from the

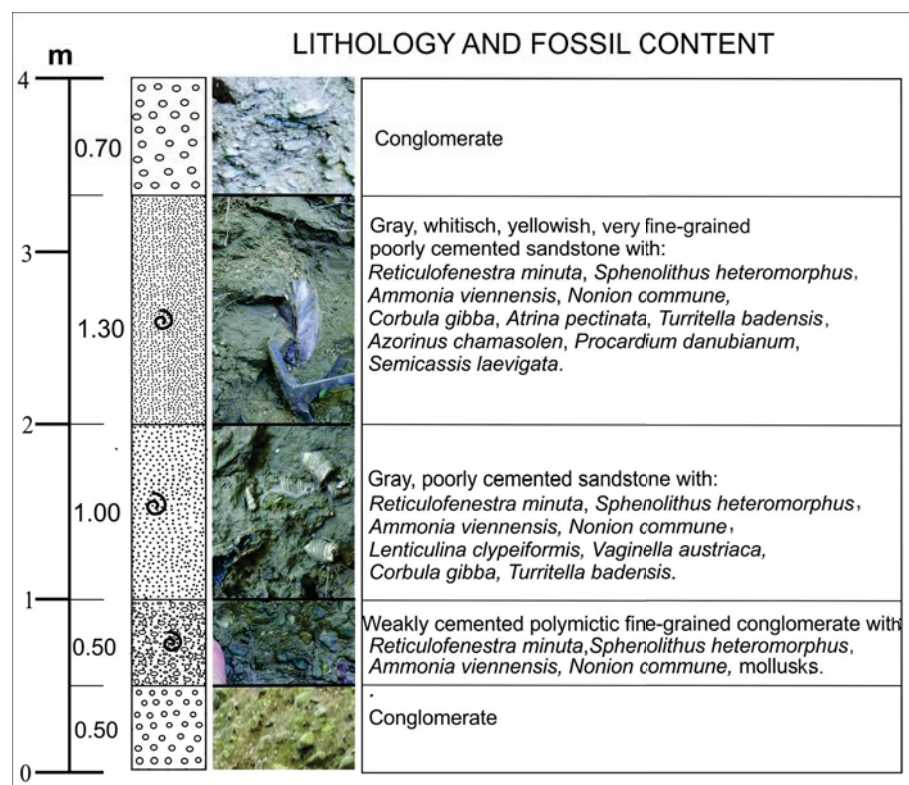


Fig. 2. Lithological column of the Lower Badenian deposits at Sumijevac section with the fossil content (according JOVANOVIĆ et al., 2018).

adjacent area of Koceljeva were studied from a biostratigraphy perspective. The lowermost and uppermost parts of the described outcrop have not been investigated due to the lack of fossils. Transition of the lowermost part of the succession towards the first fossiliferous bed was not recorded. The series of coarse conglomerates a few meters thick are located along the Sumijevec stream, not far from described section. It is possible that conglomerates from the layer 1 (Fig. 2 e) corresponds to Middle Miocene (Badenian). The basal conglomerate contains large rounded clasts with size range from less than 3 mm to over 40 cm. The space between them is filled with smaller particles of other sedimentary materials.

*viennensis*) corresponds to the Rotalid Zone, also known as Impoverishment Zone (PAPP & SCHMID, 1985). On the southern boundary of the Central Paratethys, in addition to other foraminiferal zones of Badenian, the local Zone *Ammonia viennensis* and *Nonion commune* (VRABAC et al., 2006, 2007), as well as the upper Zone *Ammonia viennensis* are separated (VRABAC, 1989). There are two essential differences between these zones. The first difference is a palaeogeographic-superposition character. The lower Badenian *Ammonia viennensis* Zone and *Nonion commune* Zone were deposited during the transgression of Central Paratethys and transgressively overlain the rocks of different composition and age

(EREMIJA, 1987; 1987a; VRABAC, 1999). In Bosnia, these are followed by the lower Badenian *Trilobatus trilobus* Zone and *Orbulina suturalis* Zone (VRABAC, 1999).

The upper Badenian *Ammonia viennensis* Zone is deposited during the regression of the Central Paratethys (SENEŠ, 1974; SOKLIĆ, 1988; VRABAC et al., 2015), and conformably overlies the upper Badenian *Bolivina dilatata maxima* Zone. Another very important difference is a palaeontological character. By the end of the Badenian there was a decrease in salinity, which is why the organic world in the uppermost zone of upper Badenian is considerably poorer than in the lower Badenian zone (VRABAC, 1999) when the salinity of the sea water was normal. Due to the decrease of salinity, shells of *Ammonia* are significantly smaller in the uppermost part

of upper Badenian and lower Sarmatian. The foraminiferal tests reduce by different stress that can be induced by fluxes in salinity, CO<sub>2</sub>, O<sub>2</sub>, pH, etc. The tests of *Ammonia* from Sumijevec Stream are quite large

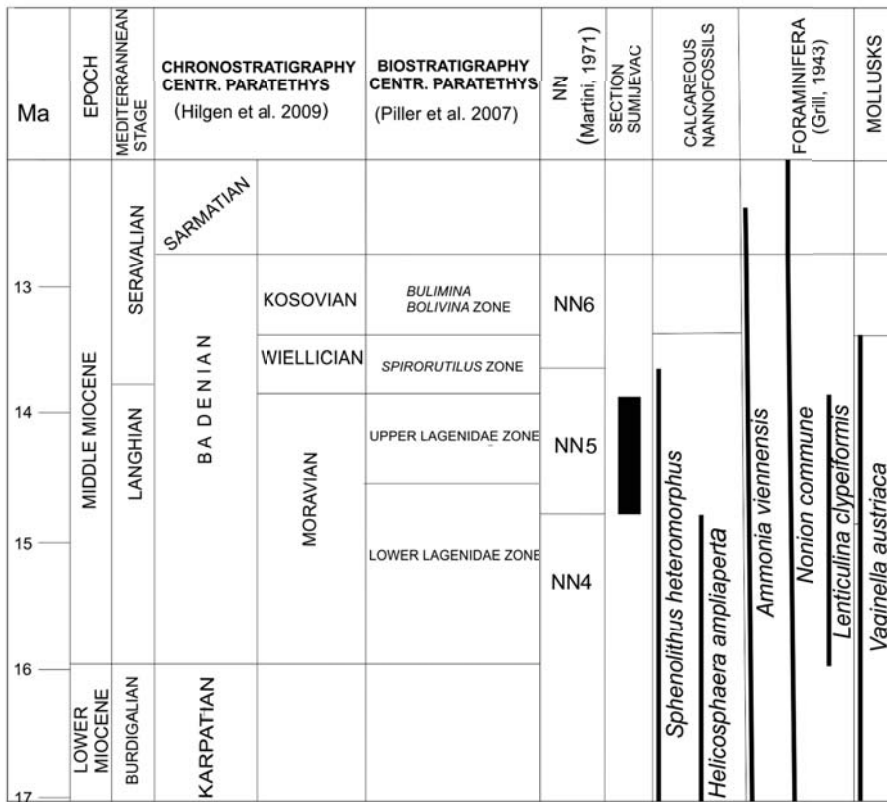


Fig. 3. Stratigraphic distribution of the calcareous nannofossils, foraminifera and mollusks in the Sumijevec section near Koceljeva. Stratigraphic correlation table and global chronostratigraphy after HILGEN et al. (2009), NN zone after LOURENS et al. (2004); PILLER et al. (2007), HOHENEGGER et al. (2009), PEZELJ et al. (2013), SANT et al. (2017).

Based on foraminifera GAGIĆ (1968) and PETROVIĆ (1985) attributed these deposits to the Upper Badenian *Rotalia beccarii* Zone (= *Ammonia viennensis*). In Vienna Basin, *Rotalia beccarii* Zone (= *Ammonia*

which characterized lower Badenian forms. All of the above mentioned characteristics are recorded at several profiles in the northern Bosnia. In this area (Tuzla basin, Ugljevik region, etc.), the lowermost part of lower Badenian is also presented by the *Ammonia viennensis* Zone and *Nonion commune* Zone corresponding to the nannoplankton Zone NN5, according to VRABAC et al. (2006, 2011, 2013, 2017) and ĆORIĆ et al. (2007). This zone is synchronous with the Lagenide Zone of Vienna Basin (GRILL, 1943; PEZELJ et al., 2013).

A characteristic feature is the presence of *Corbula gibba* and *Turritella badensis* showing a marked frequency in the deposits. Among mollusks especially the juvenile forms of the opportunistic species *Corbula gibba* were observed. The study of mollusks fauna indicates an influence of the Middle Miocene Climatic Optimum that preceded the Middle Miocene Climatic Transition (approximately 14 Ma ago) (HAMON et al., 2013), and overlaps in time with the end of Miocene Climatic Optimum. The Middle Miocene Climate Optimum (MMCO) occurred between 17–14.50 Ma according to ZACHOS et al., (2008). This diverse fossil material is typical for the Langhian of Central Paratethys (HARZHAUSER et al., 2003). Several thermophilous elements (especially *Semicassis*, *Procardium*, *Kalloconus*, etc.) which were recorded in the Central Paratethys during early Badenian, are identified. Several samples of *Cubitoostrea*, *Conus*, *Persistostrombus* and corals collected by Nikola Panić are housed in the Native museum in Koceljeva providing additional information on the assemblages of lower Badenian mollusca. Relatively high molluscan diversity observed in some other localities in Serbia (EREMIJA, 1987) and Bosnia (ATANACKOVIĆ, 1969; 1985) is a marker of tropical conditions in the Paratethys Sea during middle Miocene times. These results highlight how important is the study of many different sites situated on the southern margin of the Central Paratethys in order to gain a full understanding of warm climate influence in the distribution of mollusks fauna.

The lithofacial and biofacial characteristics of the studied deposits of the Sumijevac profile indicate that they were deposited in a very shallow, coastal part of the infralittoral in the sea with normal salinity. The dominance of *Reticulofenestra minuta* and *Coccolithus pelagicus* indicates shallow, marine envi-

ronment with rich nutrients input. The majority of the mollusks species in this article like many of the species recorded from the prior papers (EREMIJA, 1977; STEVANOVIĆ, 1959; DOLIĆ & KRSTIĆ, 1985) belong to the genera living in subtropical and tropical seas.

Among mollusks especially the juvenile forms of the opportunistic species *Corbula gibba* were observed. This is a species with high fertility and an enormous number of eggs and can be settled in rather unstable soft sea bottom. *Corbula* inhabits soft bottom sediments mixed with molluscan shell fragments (HRS-BENKO, 2006). This bivalve with a sedentary mode of life is very frequent in the Middle Miocene sediments of Serbia and other localities of Central Paratethys. The discovery of carbonated woods in the lower part of the succession (bed 2) also indicates an input from the terrestrial environment near coastal environment of the littoral zone. *Atrina pectinata* (pen shell) lives embedded in the sediment. The fragile shell of this bivalve is easily damaged by physical disturbance. However, unlike *Corbula gibba*, juvenile *Atrina pectinata* in sediments are usually smothered and the recoverability is likely to be low. *Atrina pectinata* from Sumijevac section with well-preserved prismatic layers composed of columnar crystals indicates the influence of weak and moderate currents. The most important palaeoecological change is observed in the increase in size and biodiversity of mollusks fauna, especially in sample No. 3. *Turritella* assemblages are common with large specimens of *Turritella badensis*. A high percentage of *Turritella* representation can also be an indication of a coastal marine environment with a rich nutrients input.

The locality Sumijevac Stream provides valuable evidence of the Koceljeva palaeoenvironments during the early Middle Miocene. The marine invertebrate fauna of Sumijevac Stream is among the richest recorded from the Badenian sediments of Serbia. The revised age of the sedimentary deposit presented here provides the necessary background information for future research of neighbouring regions.

## Conclusion

This paper presents the first detailed biostratigraphic investigation of the sedimentary succession

in the Sumijevac Stream, near Koceljeva. The results of new material collected in the 2017 are presented and the biostratigraphical implications are interpreted in more details. The deposits at this locality are abundant in fossils. However, previous investigations had yielded different stratigraphic attributions. The sediments are rich in mollusks, calcareous nanofossils, benthic foraminifera, whereas sporadically occur ostracods, otoliths and remains of echinids. Prior to these investigations the age of the Sumijevac deposits remained poorly constrained.

The study of Sumijevac succession includes biostratigraphic analysis based on calcareous nannoplankton, benthic foraminifera and pteropods. Biostratigraphically, it corresponds to the lower Badenian (*Lagenidae* Zone). Some species are very useful biostratigraphic markers, such as nanofossil *Sphaenolithus heteromorphus* and benthic foraminifera (*Lenticulina clypeiformis*, *Ammonia viennensis* and *Nonion commune*). The identification of the nannoplankton zone NN5 (MARTINI, 1971), was made on the basis of the presence of *Sphenolithus heteromorphus* DEFLANDRE and absence of *Helicosphaera ampliaperta* BRAMLETTE & WILCOXON. The last occurrence of *H. ampliaperta* defines the NN4/NN5 boundary. Furthermore, benthic foraminifera (*Lenticulina clypeiformis*, *Ammonia viennensis* and *Nonion commune* assemblage) correspond to this biostratigraphic level. Also, the presence of holoplankton species *Vaginella austriaca* indicates the lower Badenian age of these sediments. This pelagic gastropod was not recorded from the deposits of upper Badenian in Central Paratethys (BOŠNJAK et al., 2017). This is the earliest transgressive event documented in the vicinity of Koceljeva.

In addition, some species or mollusks assemblages have been used as indicators of the paleoclimate in coastal environments. The Sumijevac sediments were deposited in a very shallow, coastal part of the infralittoral with normal sea salinity. The dominance of *Reticulofenestra minuta* and *Coccolithus pelagicus* as well as some mollusks and benthic foraminifera indicates a shallow, marine environment with rich nutrients input. The revised age of the sedimentary deposit presented here provides the necessary background information for the future research of neighbouring regions. We conclude that it

is necessary to carry out the revision of the upper Badenian, determined only based on the *Rotalia beccarii* Zone (= *Ammonia viennensis*) in neighbouring regions in Serbia (Koceljeva, Rakovica stream near Belgrade, SW Banat, Sopot, Mladenovac, Arandjelovac, Kolubara basin, etc.), as well as in Bosnia and Herzegovina (Prnjavor basin, NE Kozara area, etc.), and Croatia (Borovnjak, etc.).

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## Резиме

### Први докази морске доњобаденске трансгресије код Коцељеве (западна Србија)

Поток Сумијевац се налази на око 1 km југозападно од Коцељеве (западна Србија) и садржи велики број фосила, нарочито мекушаца. Међутим, старост седимената није прецизно одређена и у ранијим радовима је различито коментарисана. Ради провере ранијих биостратиграфских закључака, током 2017. извршили смо теренска истраживања и дошли до значајних палеонтолошких података. Из три узорка седимената одређени су фораминифери и мекушци, и први пут до сада је урађена анализа седимената на кречњачки нанопланктон. На основу ових резултата је дефинисана биостратиграфска припадност проучаваних седимената.

У раду су приказани резултати добијени на основу детаљне биостратиграфске анализе фосилних асоцијација кречњачког нанопланктона, бентоских фораминифера и птеропода. Истраживања су по слојевима обухватила нанофосиле, микро и макро фауну, на основу којих је доказана доњобаденска старост седимената и њихова зонска припадност. Неке врсте представљају врло корисне биостратиграфске маркере, као што су нанофосил *Sphaenolithus heteromorphus*, бентоски фораминифери (*Lenticulina clypeiformis*), затим *Ammonia viennensis* и *Nonion commune*. Идентификација нанопланктонске зоне NN5 (MARTINI, 1971) је извршена на основу присуства *Sphaenolithus heteromorphus* и одсуства *Helicosphaera ampliaperta*, чије изумирање дефинише NN4/NN5 границу. Присуство птеропода *Vaginella austriaca* потврђује доњобаденску старост ових седимената. На основу целокупног проученог фосилног материјала може се закључити да је ово најранији трансгресивни догађај документован у околини Коцељеве.

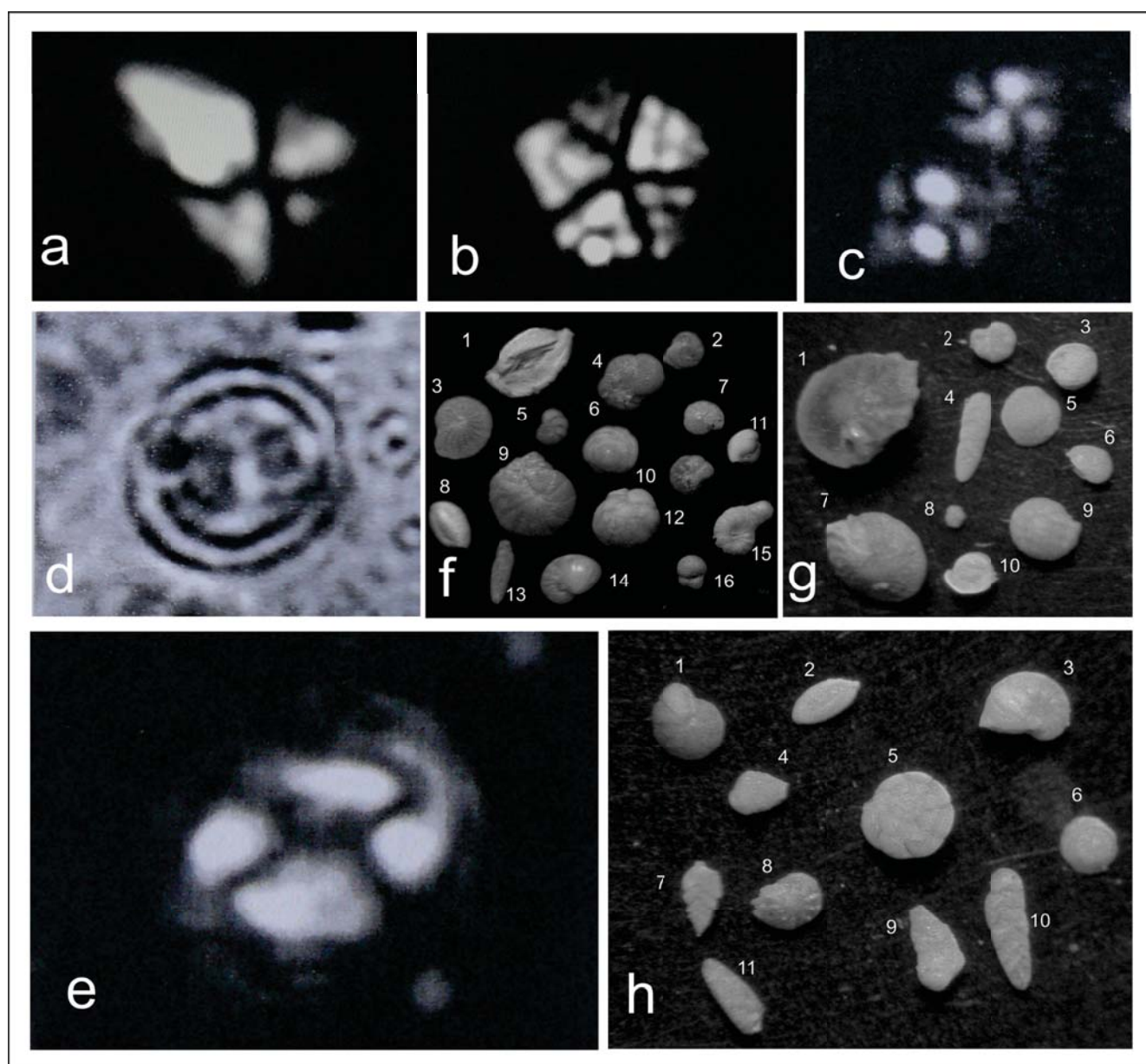
Седименти Сумијеваца су таложени у врло плитком приобалском делу инфралиторала, при нормалном салинитету. Проучавана фауна мекушаца указује на утицај средњомиоценског климатског оптимума (ММСО 17-14.50 Ма, према ZACHOS et al., 2008), који је претходио средњомиоценској климатској транзицији. Неке топловодне форме мекушаца као што су *Semicassis*, *Procardium*, *Kallosconus* и др. констатоване су и у другим ранобаденским локалитетима Централног Паратетиса. Доминација *Reticulofenestra minuta* и *Coccolithus pelagicus* указује на приобалну средину са богатим уносом хранљивих материја уз нормалан салинитет. На основу биостратиграфске анализе фосилних асоцијација утврђено је да истраживани седименти одговарају доњобаденској Лагенидној зони. Ревидована старост седимената представљених у раду указује на потребу за будућим истраживањима суседних региона. Неопходно је извршити ревизију горњег

бадена, одређеног само на основу зоне *Rotalia beccarii* (= *Ammonia viennensis*), како у Србији (Коцељева, Раковички поток код Београда, СЗ Банат, Сопот, Младеновац, Аранђеловац, Колубарски басен, и др.), тако и у Босни и Херце-

говини (Прњаворски басен, североисточно Поткозарје и др.) и Хрватској (Боровњак итд.).

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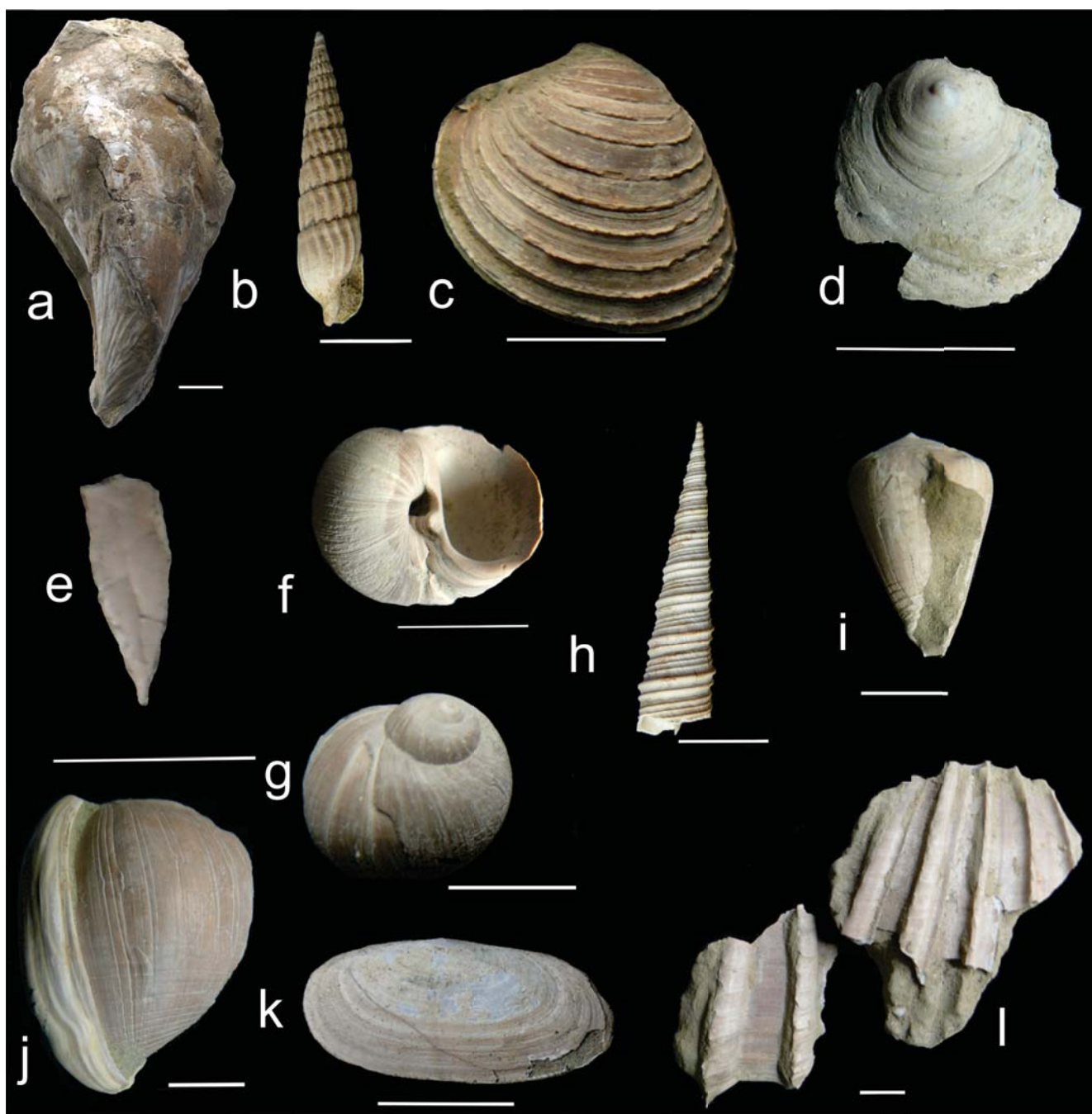
*Revised manuscript accepted June 06, 2019*



**Plate 1.** Detailed view of calcareous nannoplankton (a-e; scale bar 10  $\mu$ m) and foraminifera assemblages (f-h; dimensions of foraminifera are 0,1–0,8 mm).

**a,** *Sphenolithus heteromorphus*; **b,** *Braarudosphaera bigelowii*; **c,** *Reticulofenestra minuta*; **d,** *Coronocycus nitentes*; **e,** *Coccolithus pelagicus*; **f:** **1.** *Quinqueloculina* sp., **2.** *Lenticulina inornata*, **3.** *Elphidium crispum*, **4.** *Anomalinoides badenensis*, **5.** *Cibicidoides ungerianus ungerianus*, **6.** *Asterigerinata planorbis*, **7.** *Elphidium rugosum*, **8.** *Triloculina* sp., **9.** *Dendritina haueri*, **10.** *Porosonion granosum*, **11.** *Triloculina* sp., **12.** *Ammonia viennensis*, **13.** *Bolivina* sp., **14.** *Nonion commune*, **15.** *Spirolina austriaca*, **16.** *Trilobatus trilobus*; **g:** **1.** *Lenticulina clypeiformis*, **2.** *Porosonion granosum*, **3.** *Borelis melo melo*, **4.** *Bolivina antiqua*, **5.** *Asterigerinata planorbis*, **6.** *Nonion commune*, **7.** *Elphidium crispum*, **8.** *Globorotalia* sp., **9.** *Ammonia viennensis*, **10.** *Quinqueloculina buchiana*; **h:** **1.** *Heterolepa dutemplei*, **2.** *Pseudotriloculina consobrina*, **3.** *Nonion commune*, **4.** *Reussella spinulosa*, **5.** *Ammonia viennensis*, **6.** *Asterigerinata planorbis*, **7.** *Bolivina* sp., **8.** *Elphidium* sp., **9.** *Textularia* sp., **10.** *Textularia gramen gramen*, **11.** *Bolivina antiqua*.





**Plate 2.** Detailed view of molluscan assemblage; Scale bar: 3,00 cm (a), 1,00 cm (b–k), 0,50 cm (l)

**a**, *Atrina pectinata*; **b**, *Strioterebrum (Strioterebrum) bistratum*; **c**, *Venus nux*; **d**, *Calyptrea chinensis*; **e**, *Vaginella austriaca*; **f–g**, *Naticarius stercusmuscarum*; **h**, *Turritella badensis*; **i**, *Kalloconus berghausi*; **j**, *Semicassis laevigata*; **k**, *Azorinus chamasolen*; **l**, *Procardium danubianum*.

