

Early Miocene ostracods from the Sadovi section (Mt Požeška gora, Croatia)

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Abstract: The study of the Early Miocene (Late Otnangian/Early Karpatian) ostracod fauna from the Sadovi section (Mt Požeška gora, Croatia) led to several results concerning Neogene paleobiogeography and paleoecology. Brackish deposits of Late Otnangian and Early Karpatian age have been recognized for the first time in the North Croatian Basin. These deposits indicate the first marine ingression into the Early Miocene lake in this area. Twenty-nine ostracod species were determined, including the new taxa *Fabaeformiscandona slavonica* nov. sp. and *Herpetocypris sadovii* nov. sp.

Key words: Late Otnangian, Early Karpatian, North Croatian Basin, paleoecology, brackish environment, Ostracoda.

Introduction

The present study shows the results of ostracod analyses from the Sadovi section (Mt Požeška gora, Croatia).

During the Early Miocene this area was located in the central part of the North Croatian Basin, at the south-western margin of the Pannonian Basin System (Fig. 1, Fig. 1.1). The formation of the North Croatian Basin (in further text NCB) was connected with passive continental rifting. A syn-rift phase began during the Otnangian and lasted until the Middle Badenian. The post-rift phase lasted from the Middle Badenian to the Pliocene (Pavelić 2001).

In the NCB brackish ostracod assemblages are common in Upper Miocene deposits (Sokač 1961, 1961a, 1963, 1965, 1967, 1972), but the presence of brackish ostracod faunas in Lower Miocene deposits (Upper Otnangian/Lower Karpatian) at Sadovi locality is a new discovery.

The appearance of such fauna indicates the first ingression of marine water into the Late Otnangian/Early Karpatian lake. In the uppermost part of the section Karpatian marine marls concordantly overlay these brackish marls.

Geological setting

The Lower Miocene (Upper Otnangian/Lower Karpatian) deposits of the investigated section belong geotectonically to the Pannonian Basin System and paleogeographically to the south-western margins of the Central Paratethys. Central Paratethys extends from Bavaria to the Carpathian mountain chain (Steininger & Rögl 1979, 1984; Rögl & Steininger 1983, 1984; Rögl 1998, 1999). It was a part of the intercontinental bioprovince which began to evolve in the Oligocene and was formed due to collision of the European (Tisa-Moesia) and the African Plates (Horváth & Royden 1981; Kováč et al. 1998).

During the Miocene, connections of the Central Paratethys with the Mediterranean and the Indo-Pacific Ocean were established and interrupted several times (Steininger et al. 1988; Rögl 1996). Such unstable type of connection resulted in sea-level oscillations (Haq 1991), different depositional modes and paleoecological conditions, forcing the development of different ostracod faunas.

In the Central Paratethys the Lower Miocene Otnangian stage (~18–17 Ma) is a twofold stage (Rögl et al. 1973). Marine conditions were dominant in the early phase of the Otnangian. Except for the Northern Alpine Foreland Basin, no entirely marine environments are known (Harzhauser & Piller 2005, 2007). During the Late Otnangian, the Paratethys was isolated from the Mediterranean Sea. This sea-level drop seems to be linked with the global sea-level change of the TB2.1 cycle, lasting from ~21–17.5 Ma (Haq 1991). Brackish to freshwater sedimentary conditions prevailed, resulting in the deposition of *Rzehakia*/*Oncophora* Beds in large areas of the Paratethys (Rzehak 1882; Rögl & Steininger 1983; Rögl 1998).

At the beginning of the late Early Miocene, during the global sea-level cycle TB 2.2, lasting from ~17.5–16.4 Ma (Haq 1991), the sea-level rose and the Karpatian stage (~17–16.3 Ma) began with transgressions. In different basins, Karpatian deposits were discordantly deposited over the Otnangian marine shales, in littoral settings over the *Rzehakia* Beds, continental deposits or over older basement units (Rögl et al. 2003). A continuous transition between the Otnangian and the Karpatian is expected only in deeper parts of the Central Paratethys, whereas all shallow marine settings display a strong discordance (Rögl et al. 2003).

In the NCB the Lower Miocene lowstand deposition is represented mainly by alluvial, fluvial and deltaic deposits. At the base of the Karpatian, this sequence is rapidly replaced by marine neritic to shallow bathyal sediments (Pavelić 2001).

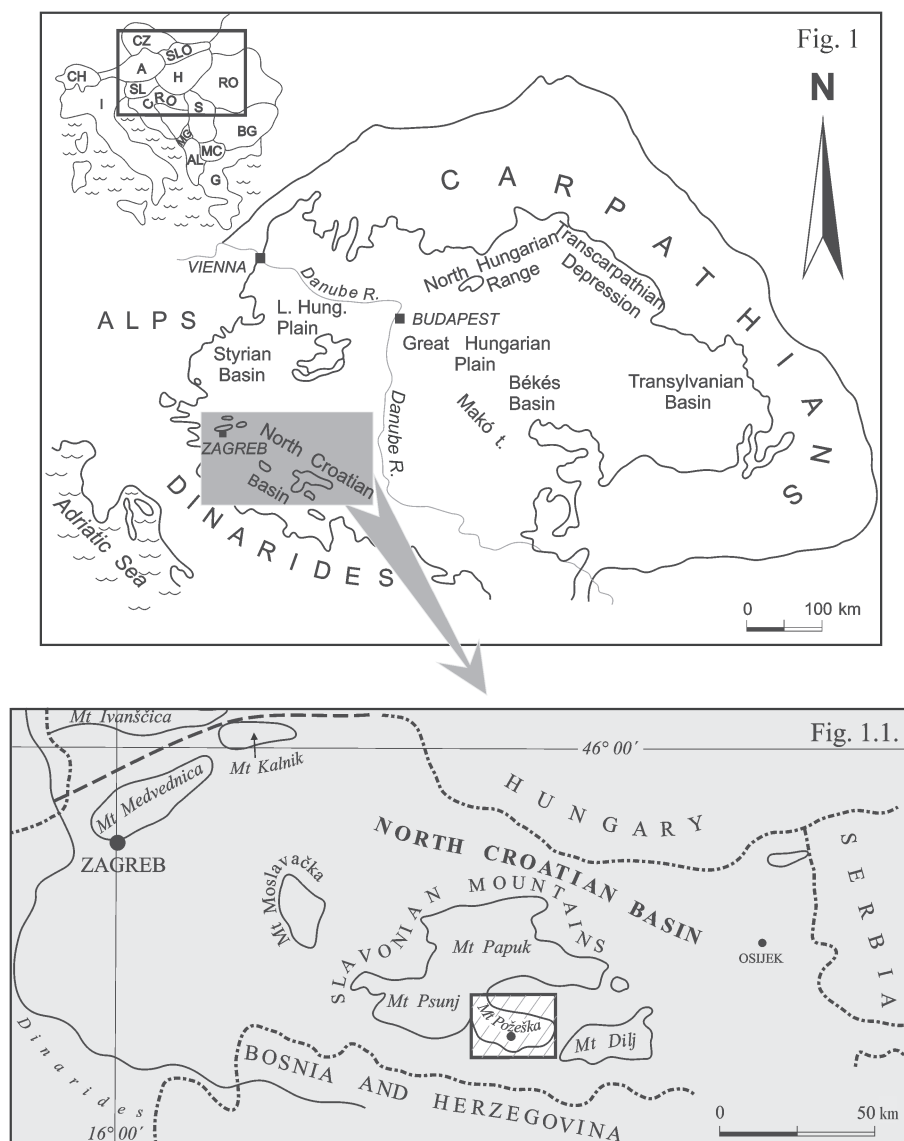


Fig. 1. Geographic setting of the North Croatian Basin within the Pannonian Basin System (after Pavelić 2001). Fig. 1.1. Location map of Mt Požeška gora with marked position (●) of the Sadovi section (after Pavelić 2001).

Formation of a sedimentary basin in the area of the Slavonian Mts started in the Oligocene with freshwater deposits (Pavelić et al. 1998). Two depositional phases were recognized by Pavelić (2001). The first phase was characterized by the accumulation of predominantly breccias and conglomerates with subordinate sand and siltstones deposited in a braided alluvial plain and under semi-arid climate conditions (Pavelić et al. 1998). During the second depositional phase a freshwater lake was formed in the area of the Slavonian Mts, in which silts and sands with sporadic layers of gravels, tuffs and tuffites were deposited. The endemic ostracod and molluscs faunas are found together with fossil plants (Pavelić et al. 1998). The second depositional phase was characterized by a shift to humid climate conditions. Lacustrine conditions were replaced by marine environments during the Karpatian time (Pavelić 2001).

Study site and methods

Study site

The Sadovi section is located in the southern part of Mt Požeška gora on the top of the Sadovi hills, along a forest road. The section is about 500 m long, and the total real thickness of the Lower Miocene sequence is 150 m. All 32 samples were collected from marls (Fig. 2). Besides the ostracods, remains of plants, molluscs and fishes were found. The colour of the marls varies from yellow, brownish-grey to olive-green.

In the first 30 meters of the section, the marls are laminated and rich in plant fragments, ostracods and fish bones. In the central part of the section (65–80 m) the marls are laminated, contain thin films of bitumen and rich ostracod faunas. Twenty five meters of the section are not exposed. Between samples Sa 29 and Sa 30, the contact with the Karpatian marine sediments has been noticed.

Methods

The collected marl samples were disaggregated by soaking in a hydrogen peroxide solution for 24 hours, then washed through sieves (0.5; 0.25; 0.125; 0.063 mm) and dried. Some of the samples needed extra cleaning and were soaked again in hydrogen peroxide and treated ultrasonically for approximately 20 seconds. 100 g of each dried residue was observed under a

stereomicroscope. Ostracods and other remains (foraminifers and gastropods) were hand-picked, counted and determined. Ostracods were picked qualitatively but not selectively, in order to preserve the relative composition of the thanatocoenose.

Six samples were selected for insoluble residue and carbonate content analysis. They were treated with 10% HCl and the carbonate content was measured. The insoluble residue, after treatment with HCl, was washed and thin sections were prepared.

Photographs were made with a SEM at the Geological Department of the Faculty of Science in Zagreb. For photographing we used two different detector types: BSE — Back Scatter Detector and SE — Secondary Electron Detector.

All ostracod specimens are stored in the archive collection of the Croatian Geological Survey (Inv. No. HGI-CGS Hr/Sa 2006/HTV).

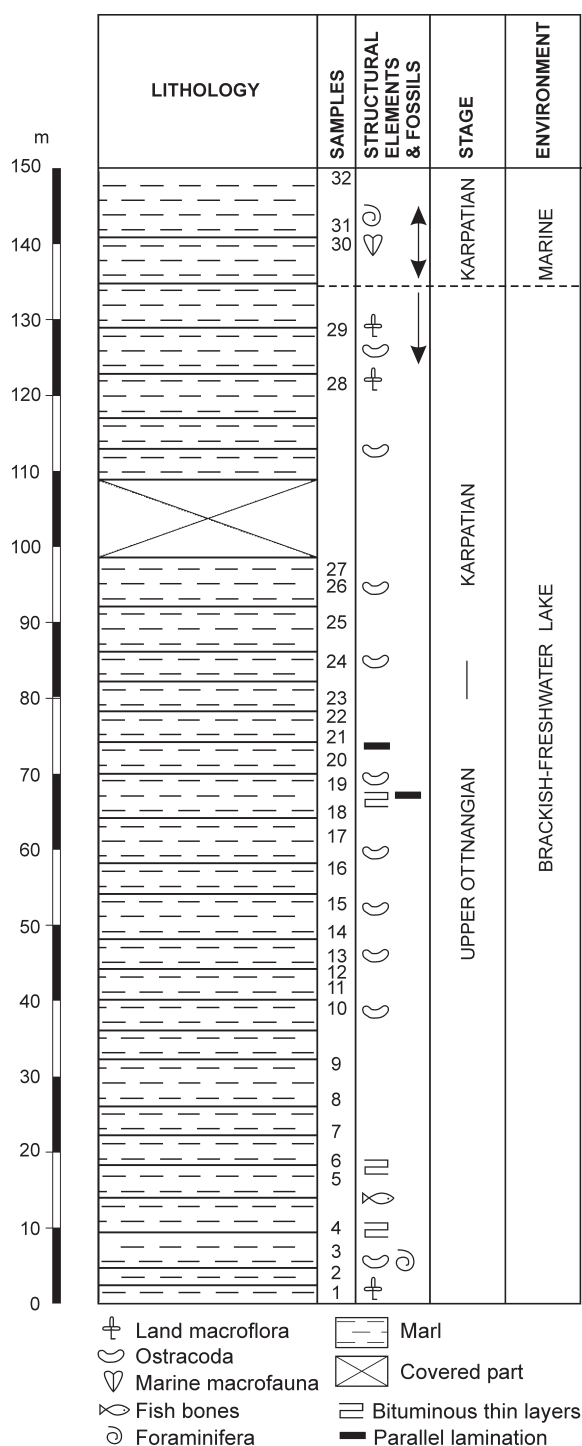


Fig. 2. Stratigraphical log of the Sadovi section.

Results

Ostracod distribution

Altogether, 29 species belonging to 18 genera and 5 families (Darwinulidae, Candonidae, Cyprididae, Limnocytheridae and Cytherideidae) were identified. Some of the taxa (13) remain in open nomenclature, 6 species are left in open nomenclature, two species are new (Table 1).

A brackish ostracod fauna was found in 26 samples. Only the uppermost three samples (Sa 30–32) of the section represent a marine fauna; we recognized juvenile valves of marine Karpatian ostracods (*Henryhowella* sp.), and benthic and planktonic foraminifers (*Svratkina* sp., *Coryphostoma* cf. *digitalis*, *Tenuitella* sp., *Globigerinoides* sp., *Cassigerinella globulosa*). This environmental change was caused by the influx of sea water into the lake. The marine depositions will not be part of this investigation. Three samples (Sa 4, Sa 5, Sa 14) did not yield any fossils.

The most abundant and frequent species in the samples from the Sadovi section are: *Herpetocypris* sp. (22 records), *Candona* (*Pontoniella*) sp. and *Candona* sp. (both 13 records) and *Fabaeformiscandona pokornyi* (11 records). The diversity varies throughout the section, and is generally low.

The maximum number of species (11) was reported in samples Sa 2 and Sa 9. Other samples with relatively high numbers of species are Sa 18 (10 species), Sa 7 (9 species) and Sa 1, Sa 10, Sa 28 (8 species). In other samples the number of species varies between 4 and 8, and 5 samples contain only 2 species.

The identified ostracod species (Table 1) can be divided into two groups. The first group includes the species from samples 1 to 18 of Sadovi section. These samples point to a brackish environment with salinities ranging from oligohaline or (low) mesohaline.

The second group is represented by the species from samples 19 to 29, which indicate the gradual decrease of salinity.

A few species appear exclusively in the first group: *Fabaeformiscandona slavonsica* nov. sp., *Cyprideis sublittoralis*, *Heterocypris* cf. *francofurti*, *Amplocypris* sp., *Cypris* sp., *Darwinula stvensoni*, *Eucypris* cf. *dulcifons*, *Paralimnocythere rostrata*, and three *Potamocypris* species: *P. fulva*, *P. cf. gracilis*, *P. cf. arcuata*. The accompanying species are *Fabaeformiscandona pokornyi*, *Candona* (*Caspiolla*) sp., *Candona* (*Pontoniella*) sp., *Cypridopsis biplanata*, *Herpetocypris* sp. and *Herpetocypris sadovii* nov. sp. In the uppermost part of the first level *Candona* (*Lineocypris*) sp. and *Candona* (*Typhlocypris*) sp., have the first common occurrence. A single valve of *Aurila* sp. and a few benthic foraminifers *Aubignyna perlucida* were found in sample Sa 2.

The second group of samples (from Sa 19 to Sa 29) contains most of the species from the first group. The dominant species in the second group are *Herpetocypris* sp., *Fabaeformiscandona pokornyi* and *Candona* (*Pontoniella*) sp.

Herpetocypris sp. gradually becomes more common from the end of the first level to the end of the section. The species which are present only in the second group with very few valves are *Pseudocandona praecox*, *Mediocypris* cf. *candonaeformis* and *Dolerocypris* sp. In contrast to the first group *Candona* (*Typhlocypris*) sp. is more common in the second group. *Candona* (*Lineocypris*) sp., *Candona* (*Caspiolla*) sp., *Cypria* sp. and *Herpetocypris sadovii* nov. sp. occur only in the uppermost samples of the second group. *Cypria dorsalis*, *Cypridopsis biplanata* and *Eucypris* sp. are present with few valves.

The brackish ostracod fauna is autochthonous, and well preserved. The population structure of the ostracod fauna indicates low water energy of the environments and low sedimentation rates (Whatley 1983).

Table 1: Distribution of the Ostracoda in the Lower Miocene deposits of the Sadovi section (1–18 = transgressive phase; 19–29 = regressive phase). Only adult valves for each species in the samples were counted: $\triangle$ 1–2, $\blacktriangle$ 2–5, $\blacktriangle$ 5–10, $\blacktriangle$ 10–20, $\bigcirc$ 20–40.

OSTRACOD SPECIES	SADOVI (Sa)																												
	1	2	3	6	7	8	9	10	11	12	13	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29			
<i>Amplocypris</i> sp.				△			△	△			▲	▲			△														
<i>Aurila</i> sp.		△																											
<i>Candona</i> (<i>Caspiolla</i>) sp.						△	▲	▲	▲	▲	▲				▲										▲				
<i>Candona</i> (<i>Lineocypris</i>) sp.															△								△			△			
<i>Candona</i> (<i>Pontoniella</i>) sp.				▲	△		▲	▲	▲	▲					▲				▲		▲	▲	▲	▲	▲				
<i>Candona</i> (<i>Typhlocypris</i>) sp.									△						△				△		△	△				△			
<i>Candona</i> sp.	▲	▲	▲	▲			▲	▲		▲		▲		▲		▲					▲		▲		▲	▲			
<i>Candonopsis</i> sp.		▲																											
<i>Cypria dorsalis</i> Malz & Moayedpour	▲	▲	▲		▲	▲	▲													△	△								
<i>Cypria</i> sp.								▲																		▲			
<i>Cyprideis sublittoralis</i> Pokorný		⬤			▲		▲					▲	▲																
<i>Cypridopsis biplanata</i> Straub	▲	▲	▲															▲								▲			
<i>Cypris</i> sp.							▲																						
<i>Darwinula stevensoni</i> Brady & Robertson	△																												
<i>Dolerocypris</i> sp.																			△				△						
<i>Eucypris</i> cf. <i>dulcifons</i> Diebel & Pietrzeniuk					▲																								
<i>Eucypris</i> sp.	▲	▲			△											△			▲	▲			▲			▲			
<i>Fabaeformiscandona</i> cf. <i>pokornyi</i> (Kheil)	▲					△												▲		▲			▲						
<i>Fabaeformiscandona pokornyi</i> (Kheil)		⬤	⬤	⬤	⬤							▲	▲			▲					⬤	▲		▲	▲				
<i>Fabaeformiscandona slavonica</i> nov. sp.	⬤	⬤	▲					▲								▲													
<i>Herpetocypris sadovii</i> nov. sp.								▲	▲			▲				▲										▲			
<i>Herpetocypris</i> sp.				△	▲	▲	▲	▲	▲	▲	▲		▲	▲	⬤	▲	⬤	▲	⬤	⬤	⬤	⬤	⬤	▲	⬤	⬤			
<i>Heterocypris</i> cf. <i>francofurti</i> (Lienenklaus)					△								▲																
<i>Mediocypris</i> cf. <i>candonaeformis</i> Straub																							△						
<i>Paralimnocythere rostrata</i> (Straub)	▲	▲	▲			△	▲						△			▲													
<i>Potamocypris</i> cf. <i>arcuata</i> Sars								▲																					
<i>Potamocypris fulva</i> (Brady)		△									△																		
<i>Potamocypris</i> cf. <i>gracilis</i> Sieber					△																								
<i>Pseudocandona praecox</i> (Straub)																			△										

Mineralogical analyses and carbonate content

Carbonate content in marl samples SA 4, SA 7, SA 14, SA 16 and SA 19 varies from 46.3 to 55.0 %. Sample SA 30 is a clay rich marl with 13.1% carbonate content. Samples from Sadovi contain a very small amount of silty siliciclastic detritus. The mineral composition of the insoluble residue in the analysed samples is quite homogeneous. Non-undulose monocrystalline subrounded or subangular quartz grains and altered feldspar grains dominate. Non-altered feldspars and twinned plagioclase are less abundant. The lithic fragments are scarce, with domination of shale fragments and some chert fragments.

A very small amount of heavy minerals is present in the samples. The most abundant among them are resistant tourmaline and garnet, accompanied by rutile, zircon, staurolite, amphibole, titanite, biotite and chlorite. Opaque minerals are also present. In the sample SA 19 opaque minerals dominate,

while the composition of the translucent heavy minerals is the same as in other samples.

The source of clasts could be related to igneous and metamorphic rocks from the vicinity. The small amount of siliciclastic components indicates calm depositional conditions and a very restricted terrigenous input.

Discussion

Ostracods from brackish waters are valuable tools in paleo-environmental reconstruction and in environmental studies. The main parameters which can be monitored with brackish water ostracods are salinity and hydrochemistry, water depth, substrate, oxygen and productivity, temperature and climate (Frenzel & Boomer 2005). The composition of ostracod assemblages from our section depends mainly on the salinity and depth of the lake water.

Brackish-water ostracods are normally found in transitional environments or in inland saline lakes (Remane 1971). The different biotopes appear and disappear at various levels in a stratigraphic succession, following the dynamics of transgression and regression through time (Do Carmo et al. 1999). In the Western Paratethys, the Late Ottnangian regression initiated the development of a shallow brackish basin, and presence of planktonic larval development in gastropods indicates a connection with the open sea (Kowalke & Reichenbacher 2005). In the Sadovi section deposition of Upper Ottnangian and Lower Karpatian brackish water sediments is a consequence of a marine ingression into the freshwater lake, which is the first signal of the new transgression in the Karpatian.

During the Early Ottnangian a freshwater lake existed in the area of the Mt Požeška gora (Kochansky-Devidé 1979; Pavelić et al. 1998; Pavelić 2001). The oldest alluvial and lake clayey deposits lack ostracods, and marly sediments of a oligotrophic freshwater lake contain ostracod communities (Hajek-Tadesse et al. 2006).

The increase of water salinity in the Late Ottnangian and Early Karpatian, which is observed in the Sadovi section for the first time, was caused by the ingression of marine water into the lake. Ingression of marine water was documented by the composition of ostracod fauna, especially with the occurrence of typical brackish ostracod taxa: *Cyprideis sublittoralis* and *Aurila* sp. together with scarce foraminifers (*Aubignyna perlucida*).

The occurrence of the genus *Cyprideis* in the Sadovi section plays an important role in the identification of brackish environments. The genus *Cyprideis* is not typical for the Lower Miocene deposits of the Central Paratethys. It is common in the Upper Miocene deposits of Croatia (Sokač 1972). For the Late Sarmatian and Pannonian (12 to 8.5 Ma) in the Molasse Basin, the occurrence of *Cyprideis* spp. and candonid species indicate brackish conditions (Janz & Venne-mann 2005).

In Europe the probable ancestor of the genus *Cyprideis* is *Miocyprideis* (Kollmann 1960). The evolutionary sequence of *Cyprideis* in the Amazon Basin began in the Early Miocene, and the most explosive radiation of *Cyprideis* in Western Amazon region occurred at the boundary between the Early and Middle Miocene (Langhian stage). The ancestors of *Cyprideis* in the Amazon Basin are not identified. A paleofauna of 21 endemic species of the euhaline genus *Cyprideis* lived between polyhaline and oligohaline salinity ranges during sporadic intervals of marine influence (Muñoz-Torres et al. 2006).

In contrast to brackish *Rzehakia/Oncophora* Beds of the Central Paratethys, which is a result of global sea-level decrease, Lower Miocene brackish deposits in Sadovi are the result of marine ingression.

Numerous paleosalinity studies were based on the cosmopolitan holoeuryhaline species *Cyprideis torosa*. Aladin (1993) pointed out that *C. torosa* is a brackish water ostracod of marine origin with extremely complex osmoregulatory mechanisms and is known to withstand low oxygen conditions.

Lateral sieve pores of recent and fossil *Cyprideis torosa* vary in outline from round to oval and irregular. The percentage of round pores decreases with the increase of salinity (Rosenfeld & Vesper 1977).

Gliozzi & Mazzini (1998) and Anadon et al. (2002) note that differences in paleosalinity values may be explained by mixing waters of different origin.

A connection between the salinity and nodding of *C. torosa* was noticed by Hartmann (1964), Vesper (1975), Van Harten (1996) and Keyser (2005). Nodding at low salinities is the most accepted condition, despite the fact that the controlling mechanism is poorly understood. Do Carmo et al. (1999) connect variable nodding of Middle Jurassic limnocytherid ostracods with salinity changes.

In the first group (transgressive part) of the Sadovi samples, rounded, oblong and irregularly shaped sieve pores of the species *Cyprideis sublittoralis* are distributed in almost even percentage. Rosenfeld & Vesper (1977) connected such distribution with 8 to 16 ‰ salt concentration. On the other hand, in these samples we found only unnoded forms of adults and numerous juvenile stages. Brackish water ostracods live within the uppermost few millimeters of the sediment, because much of the sediment below this level is often rich in organic material and, as a result, depleted in oxygen (Horne & Boomer 2000).

The ostracod fauna from Sadovi can be compared with the brackish ostracods from the Kirchberg Formation (Upper Ottnangian/Lower Karpatian) of the western part of the South German Molasse Basin (Witt 2000) and ostracods from the *Oncophora* Beds in the East (Witt 1999), but ostracod assemblages from Sadovi are indicative for a more saline lake environment.

Such faunal relations are more common in the Late Miocene of the Paratethys area: Styrian Basin, Turčianska kotlina Depression (Slovakia) and the Pannonian Basin (Sokač 1972; Gross 2004; Pipík & Bodergat 2004).

Beside salinity, substrate is the main factor controlling the occurrence of ostracods in brackish water (Ruiz et al. 2000). The marl deposits in the Sadovi section are horizontally laminated, they contain thin bituminous lamina, rich ostracod assemblages, plant remains and a few skeletal fish particles.

During the Late Ottnangian and Early Karpatian in the area of Mt Požeška gora an eutrophic lake existed with increasing salinity of water and low input of clastic material from the land. We recognized this event as the new, "third phase" of deposition in NCB sensu Pavelić (2001).

Most of the ostracod taxa determined from the Sadovi section prefer ponds and lakes and tolerate an increase of salinity (Meisch 2000). Dissolution of valve margins in the species *Amplocypris* sp. and bacterial activities on *Cypria dorsalta* valves are a common effect and are typical for eutrophic environments (Reeves et al. 2007).

Carbonel et al. (1988) conclude that species with "high" triangular, trapezoidal shape and elongated valves with pointed posterior (such as *Candona (Lineocypris)* sp., *Candona (Typhlocypris)* sp., *Candona (Pontoniella)* sp. and *Cypria* sp. from Sadovi) occur frequently in persistent environments with low environmental fluctuations like groundwater habitats and the sublittoral of old lakes.

The confirmation of marine ingression into the Late Ottnangian/Early Karpatian lake in the area of Mt Požeška gora gives a key for understanding the formation of analcime deposits north and south-east from the investigated sec-

tion. Ščavničar et al. (1983) studied the analcime-bearing deposits north of Sadovi in Poljanska (southern Papuk, Slavonija region) and Sirječić et al. (1974) described analcimolites south-east from Sadovi, in the Tuzla salt series (Bosnia and Herzegovina).

The genesis of sediments near Poljanska is linked to the saline alkaline lake environment. Ščavničar et al. (1983) conclude that analcime was formed by alternation of volcanic glass, as well as from other silicates in the shallow water of an unsheltered saline alkaline lake, under conditions of increasing aridity and closure of the lake. Variable composition, texture and structure of analcime-bearing deposits give the evidence of the climate shifts and the lake history (Ščavničar et al. 1983).

The registered influx of marine water into the lake before the Karpatian transgression and the appearance of the brackish ostracod fauna at Sadovi raise new questions on marine connections between the Mediterranean and the Central Paratethys.

The problem of the marine connection between the Mediterranean and Central Paratethys area remains unsolved. The Transtethyan Trench Corridor (Bistričić & Jenko 1985) was situated somewhere in the territory now forming part of Slovenia or northern Croatia. On the basis of our previous investigations and the results of our work in this paper we conclude that the possible position of the new corridor, which has not previously been well documented, is south-east of the NCB.

Conclusions

The study of ostracod assemblages from Sadovi revealed for the first time the existence of brackish deposits in the Late Ottnangian/Early Karpatian, as a result of marine ingress into the lacustrine water of the NCB. In the uppermost samples of the investigated section a continuous transition of brackish deposits into the Karpatian marine beds with scarce marine microfauna was observed.

The microfauna from the Sadovi section belong to the upper part of the Lower Miocene (Upper Ottnangian/Lower Karpatian). A more precise biostratigraphic dating is not possible on the basis of ostracods. However, paleoecological data obtained by ostracod analysis are much more significant. For the first time, based on ostracod assemblages, a wide brackish influence could be documented in the Lower Miocene deposits of the NCB.

Samples from the Sadovi section can be divided into two groups. The groups are defined on the basis of different ostracod assemblages and different trends in water salinity. In the first group (samples 1–15) we found brackish ostracod assemblages with the indicative brackish species *Cyprideis sublittoralis*, which has been detected for the first time in the Lower Miocene of the Central Paratethys. In the second group (samples 16–25) these species disappear and ostracod assemblages indicate the slight decrease of water salinity.

Qualitative analyses resulted with 29 identified ostracod species, among which two species are new: *Fabaeformiscandona slavonica* nov. sp. and *Herpetocypris sadovii* nov. sp.

Brackish deposits of the Sadovi section are the result of the marine ingress into the lake. They represent the “third phase” of development, of the NBC successively complementing the local reconstruction of the Ottnangian depositional model introduced by Pavelić (2001).

The genesis of analcime layers north and south-east of the investigated area (Sirječić et al. 1974; Ščavničar et al. 1983) can also be explained by the intrusion of sea water into the Early Miocene lake.

The detected brackish Lower Miocene (Upper Ottnangian/Lower Karpatian) deposits of the “third phase” and transgressive Karpatian marine marls, indicate the possibility of an additional marine connection between the Mediterranean and/or Indo-Pacific Ocean situated south-east of the investigated area.

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Appendix

New ostracod species

The following abbreviations are used in the description of the new ostracod species: LV and RV — left and right valves; H and L — height and length; n — number of measured specimens; ♀ and ♂ — female and male.

Class: **Ostracoda** Latreille, 1806

Order: **Podocopida** Sars, 1866

Suborder: **Podocopina** Sars, 1866

Superfamily: **Cypridoidea** Baird, 1845

Family: **Candonidae** Kaufmann, 1900

Subfamily: **Candoninae** Kaufmann, 1900

Genus: *Fabaeformiscandona* Krstić, 1972

Generic characters of this new species are according to those given by Van Morkhoven (1962). Carapace usually elongated in lateral view, greatest H close to 1/2 L. Mostly with significant sexual dimorphism. LV usually with postero-dorsal lobe, overlapping the RV (diagnosis after Meisch 2000).

The genus *Fabaeformiscandona* comprises ca. 50 recent species (Meisch 2000). The oldest fossil representatives of this genus are known from the Early and Middle Miocene of Europe (Janz 1997; Witt 1998, 2000; Schäfer 2005). Some recent species of the genus *Fabaeformiscandona* frequently occur in Pliocene and Pleistocene (Meisch 2000).

Fabaeformiscandona slavonica nov. sp.

Fig. 3.1–7

Material: 46 valves.

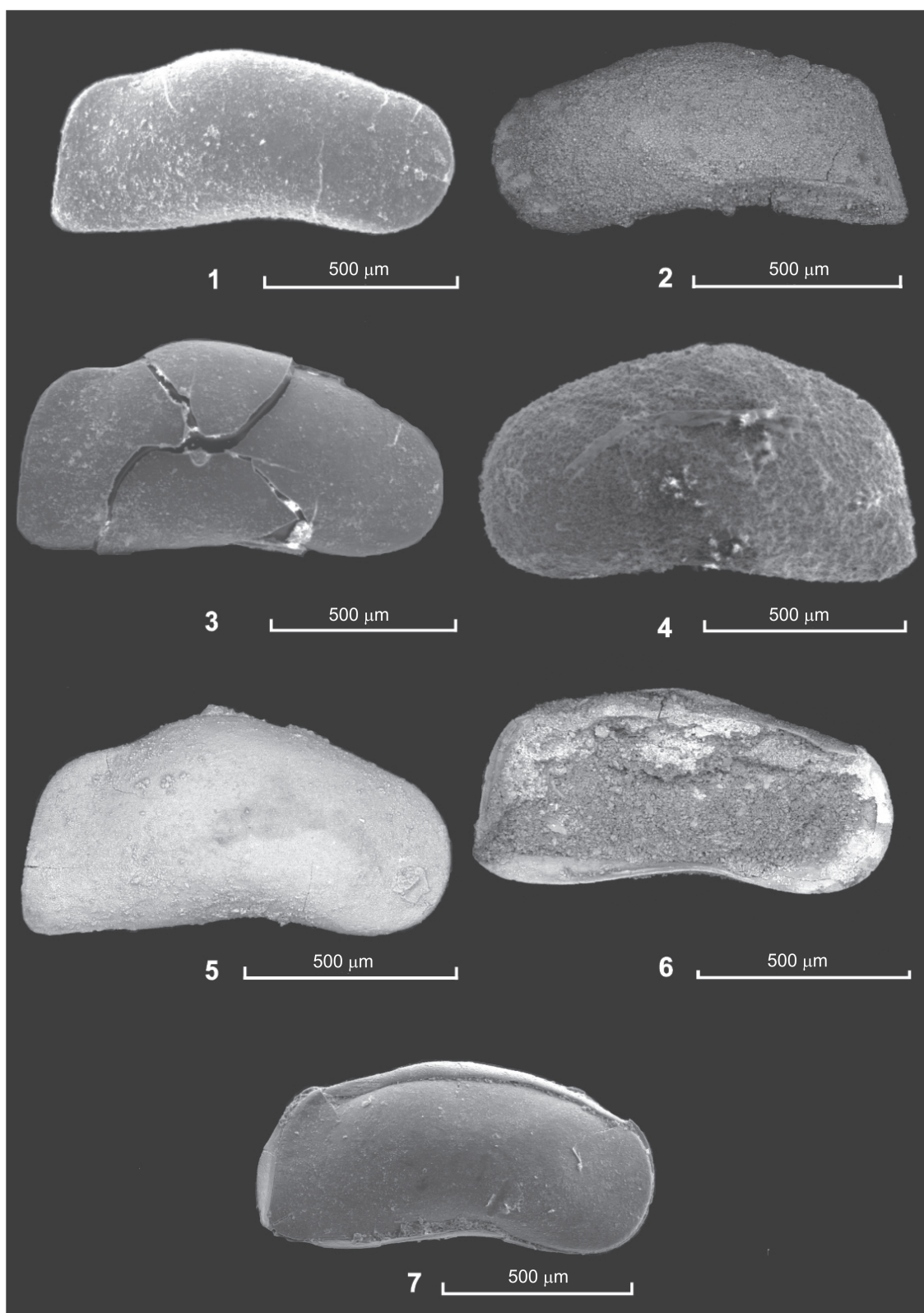


Fig. 3. SEM microphotographs of selected ostracods. **1** — *Fabaformiscandona slavonica* nov. sp., Sa 2, male right valve, external view (SE Detector). **2** — *Fabaformiscandona slavonica* nov. sp., Sa 2, male left valve, external view (SE Detector). **3** — *Fabaformiscandona slavonica* nov. sp., Sa 2, female right valve, external view (SE Detector). **4** — *Fabaformiscandona slavonica* nov. sp., Sa 3, female left valve, external view (SE Detector). **5** — *Fabaformiscandona slavonica* nov. sp., Sa 2, female right valve, external view (BSE Detector). **6** — *Fabaformiscandona slavonica* nov. sp., Sa 2, female left valve, internal view (BSE Detector). **7** — *Fabaformiscandona slavonica* nov. sp., Sa 2, female carapace, seen from the right (SE Detector).

Etymology: Type locality is situated in Slavonia, region in eastern Croatia.

Holotype: Right valve, Fs-1, HGI-CGS Hr/Sa 2006/HTV. Fig. 3.1.

Type-level: Lower Miocene/Upper Oligocene–Lower Karpatian, brackish deposits.

Type-locality: Sadovi, Mt Požeška gora, North Croatian Basin.

Paratypes:

Left valve Fs-2, HGI-CGS Hr/Sa 2006/HTV. Fig. 3.2.

Right valve Fs-3, HGI-CGS Hr/Sa 2006/HTV. Fig. 3.5.

Left valve Fs-4, HGI-CGS Hr/Sa 2006/HTV. Fig. 3.4.

Diagnosis: *Fabaeformiscandona slavonica* is best recognized in the external lateral view of right valve. The dorsal margin of RV is specific with swale.

Description: Valves smooth, strongly calcified, with variable H/L ratio; greatest H situated distinctly behind mid-length. Carapace laterally compressed in dorsal view. Dorsal margin of the LV overlaps the RV. Sexual dimorphism present.

Male. Valves elongated less high than in the female. Dorsal margin slightly convex. Ventral margin slightly concave. Anterior end rounded. Posterior end almost straight and obliquely cut, forming a sharp angle with the postero-ventral margin. LV (interior) slightly turned inwards in the upper part of the posterior end. Males always present.

Female. RV with similar shape to male RV, slightly higher than male. RV with swale on dorsal margin. LV with distinct convex dorsal margin, gently and continuously sloping down towards anterior and posterior ends (swale missing). While anterior end is gently rounded, posterior end is almost evenly cut off, forming a small point with the afferent ventral margin. LV with maximum width in the central part.

Measurements (mm):

Holotype RV ♂ (Fs-1, HGI-CGS Hr/Sa 2006/HTV): L = 1.04, H = 0.43.

Paratype LV ♂ (Fs-2, HGI-CGS Hr/Sa 2006/HTV): L = 1.02, H = 0.38.

RV ♀ (Fs-3, HGI-CGS Hr/Sa 2006/HTV): L = 1.01, H = 0.53.

LV ♀ (Fs-4, HGI-CGS Hr/Sa 2006/HTV): L = 1.02, H = 0.54.

Ranges of sizes of selected specimens:

L (LV) ♂ = 1.03–0.99 mm (n=2); H (LV) ♂ = 0.39–0.36 mm (n=2).

L (LV) ♀ = 0.98 mm (n=1); H (LV) ♀ = 0.49 mm (n=1).

L (RV) ♂ = 1.03–0.94 mm (n=5); H (RV) ♂ = 0.41–0.37 mm (n=5).

L (RV) ♀ = 1.00–0.96 mm (n=2); H (RV) ♀ = 0.51–0.49 mm (n=2).

Remarks: The *Fabaeformiscandona slavonica* nov. sp. has to be compared to the known described Miocene species: *Fabaeformiscandona fabaeformis* (Fischer) and *F. cf. balatonica* (Daday) (sensu Janz 1997: p. 3, figs. 3–10; p. 4, figs. 1, 2); *F. pokorny* (Kheil) (sensu Witt 1998: p. 1, figs. 2–8; 2000: p. 2, fig. 3); and *Fabaeformiscandona* sp. (sensu Schäfer et al. 2005: p. 2, figs. 9–11), however, none is close to the new species.

Other *Fabaeformiscandona* species have been investigated. The new species differs from all of these. In general, *Fabae-*

formiscandona slavonica nov. sp. can easily be distinguished from all its congeners in the postero-dorsal part of the male and female RV. Only the carapace of recent *Fabaeformiscandona fabaeformis* (Fischer) is similar in dorsal view. Female LVs of *Fabaeformiscandona slavonica* nov. sp., resemble those of *Fabaeformiscandona levanderi* (Hirschmann) in shape. The female LVs can easily be distinguished from each other by the posterior and postero-ventral part of the valve.

Family: **Cyprididae** Baird, 1845

Subfamily: **Herpetocypridinae** Kaufmann, 1900

Genus: *Herpetocypris* Brady & Norman, 1889

The new species belongs to the genus *Herpetocypris*. Carapace elongated in lateral view, about 1.5–2.6 mm long. The height always less than half the length. Both ends are rounded. Dorsal margin weakly rounded to almost straight. Carapace laterally moderately compressed. Fused valve zones small, pore canals straight, marginal septae absent. LV overlaps RV along the entire valve margin (diagnosis after Van Morkhoven 1963; Meisch 2000).

Six certain and several dubious species have been recorded from Europe (Meisch 2000). Fossil species of *Herpetocypris* are known from the Early and Middle Miocene of Europe (Sokač 1979; Sokač & Krstić 1987; Jurišić-Polšak et al. 1993; Witt 1999, 2002). The fossil records for some recent species of genus *Herpetocypris* are common from the Pleistocene (Van Morkhoven 1963; Meisch 2000).

Herpetocypris sadovii nov. sp.

Fig. 4.1–3

Material: 15 valves.

Etymology: After the type section in which it was first found.

Holotype: Right valve, Hb-1, HGI-CGS Hr/Sa 2006/HTV. Fig. 4.3.

Type-level: Lower Miocene/Upper Oligocene–Lower Karpatian, brackish deposits.

Type-locality: Sadovi, Mt Požeška gora, North Croatian Basin.

Paratype: Left valve Hb-2, HGI-CGS Hr/Sa 2006/HTV, sample Sa 10.

Diagnosis: Distinctly elongated valve with rounded anterior and posterior end.

Description: A large, elongate, well calcified valve. Smooth surface. Dorsal margin almost straight in the middle and sub parallel to the ventral line. Transitions from dorsal margin to anterior and posterior ends are gradual. Ventral margin slightly concave in the middle. Anterior and posterior end rounded, but anterior end broader than the posterior one.

Fused valve zones small. Marginal pore canals straight and short. Muscle scars weakly evident. No distinct sexual dimorphism could be detected in the examined material.

Measurements (mm):

Holotype RV Hb-1, HGI-CGS Hr/Sa 2006/HTV: L = 1.34, H = 0.48.

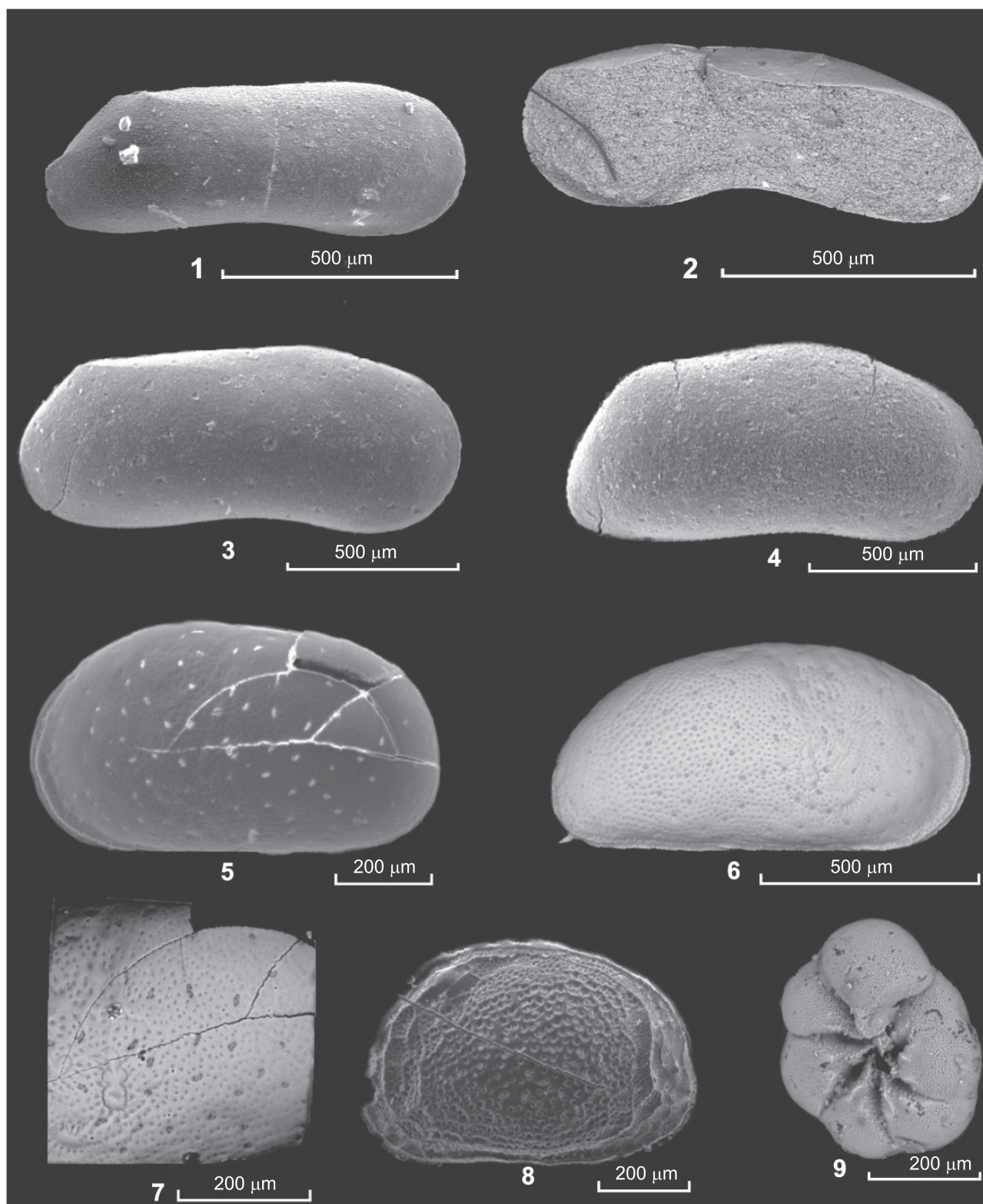


Fig. 4. SEM microphotographs of selected microfossils. **1** — *Herpetocypris sadovii* nov. sp., Sa 9 right valve, external view (SE Detector). **2** — *Herpetocypris sadovii* nov. sp., Sa 10 right valve, internal view (SE Detector). **3** — *Herpetocypris sadovii* nov. sp., Sa10, right valve, external view (SE Detector). **4** — *Herpetocypris* sp., Sa 19, right valve, external view (SE Detector). **5** — *Cyprideis sublittoralis* Pokorný, Sa 2, female left valve, external view (SE Detector). **6** — *Cyprideis sublittoralis* Pokorný, Sa 2, male right valve, external view (BSE Detector). **7** — *Cyprideis sublittoralis* Pokorný, Sa 2, selected detail of left valve, with central muscle scars and sieve pores (BSE Detector). **8** — *Aurila* sp., Sa 2, left valve, external view (SE Detector). **9** — *Aubignyna perlucida* (Heron-Allen & Earland), Sa 2 (SE Detector).

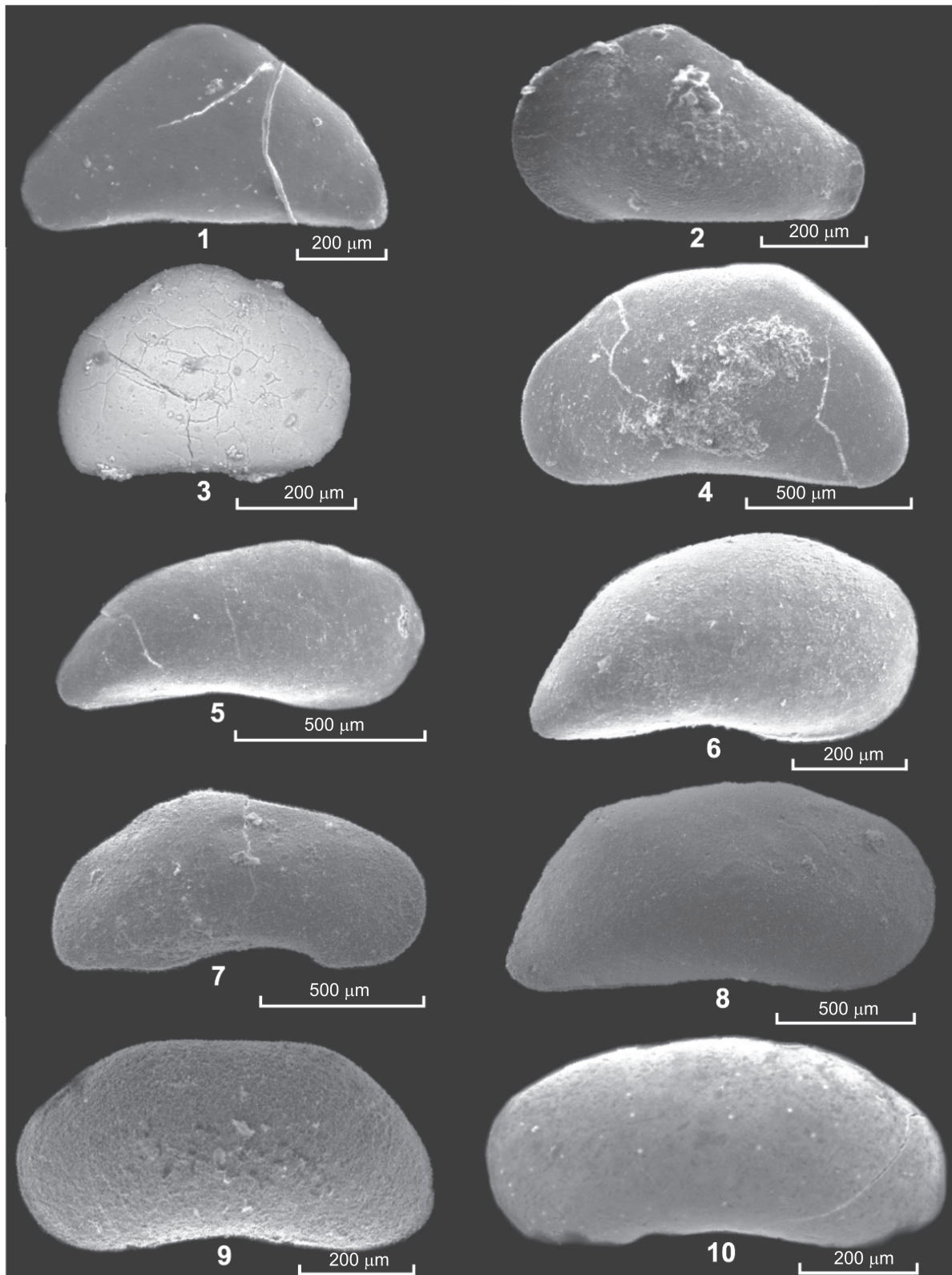


Fig. 5. SEM microphotographs of selected ostracods. **1** — *Candona (Typhlocypris)* sp., Sa 22, left valve, external view (SE Detector). **2** — *Cypris* sp., Sa 9, left valve, external view (SE Detector). **3** — *Cypria dorsalta* Malz & Moayedpour, Sa 7, left valve, external view (BSE Detector). **4** — *Potamocypris cf. arcuata* Sars, Sa 10, left valve, external view (SE Detector). **5–6** — *Candona (Pontoniella)* sp., Sa 24, right valves, external view (SE Detector). **7** — *Candonopsis* sp., Sa 2, right valve, external view (SE Detector). **8** — *Candona (Casiolla)* sp., Sa 12, right valve, external view (SE Detector). **9** — *Fabaeformiscandona pokornyi* (Kheil), Sa 20, left valve, external view (SE Detector). **10** — *Candona* sp., Sa 12, right valve, external view (SE Detector).

Paratype LV Hb-2, HGI-CGS Hr/Sa 2006/HTV:
L = 1.19, H = 0.46.

L (LV) = 1.21 mm (n = 1); H (LV) = 0.46 mm (n = 1).

L (RV) = 1.33–1.29 mm (n = 3); H (RV) = 0.47–0.42 mm (n = 3).

Remarks: *Herpetocypris sadovii* nov. sp. comes close to *Herpetocypris chevreuxi* (Sars). The two species differ in the following characters: a) size — *H. chevreuxi* are longer than *H. sadovii*; b) ventral margin — in *Herpetocypris sadovii* nov. sp. ventral margin is more concave; c) posterior end — different shape in postero-dorsal part of valve. The new species *Herpetocypris sadovii* differs from the Early and Middle Miocene *Herpetocypris* species: *Herpetocypris* sp. A (sensu Witt 1999: p. 2, fig. 6–9; 2002: p. 2, fig. 5–8); *Herpetocypris snegotini* (Krstić) (sensu Sokač 1979: p. 2, figs. 1, 3, 5); *Herpetocypris* sp. (sensu Jurišić-Polšak et al. 1993: p. 1, figs. 1, 6, 9, 12) in shape of valves, especially in area of dorsal margin, and anterior/posterior ends.

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