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# FOSSILS FROM THE DRILL HOLE GS-1 NEAR GACKO, SE DINARIC ALPS

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This paper presents the study of a part of a column under the main coal measure at the drill hole GS-1, including the first and the second underlying coal seams and some of the sediments beneath them. Among the recorded fossils gyrogonites of Charophyta prevail; previously unknown among meiofossils in the area, they indicate depths of water to ca. 7 m. The mollusks comprise species known from Gacko and other sites in the Dinaric Alps. The ostracodes are comparable to those known from freshwater biofacies of Middle Europe.

The age was corroborated by *Nitellopsis merianii*, an organ-species of Eurasian Miocene and "*Harrisichara*" *sp.* a descendant of the Eocene-Oligocene genus *Harrisichara*. The final decision on age was reached according to the presence, in close lying Plevlja, of the organ-species *Rhabdochara langeri*, a key fossil for Lower Miocene upper part and equivalents of Burdigalian.

**Key words:** Charophytes, gastropodes, ostracodes, freshwater, Lower Miocene, Hercegovina.

## INTRODUCTION

**Geological setting.** The importance of the borehole GS-1 lies in the description of the poorly known lower part of the Dinaride Lake system (Krstić *et al.* 2003). There ecology of charophytes and ostracodes, as the position of different mollusks, was unknown. Ostracodes of the upper part, above the main coal seam, were studied in several sites (Krstić 1987, 2000).

The Gacko coal-bearing depression lies in the SE part of the Dinaric Alps. Its Neogene was divided by Milojević (Milojević 1966, Čičić & Milojević 1977) into 11 units. The Explanatory booklet of BGM "Gacko" (Mirković *et al.* 1980) distinguishes it from bedrock to the top: "Basal conglomerate", the "Underlying sediments with the II underlying coal seam", overlain by "Marls with *Fossarulus* and the First underlying coal seam", "Melanopsis marl with main coal seam" and only two more units above them. Olujić (Krstić *et al.* 2007) performed the column as presented here (Fig. 1).

## MATERIAL AND METHOD

This structural drill hole was studied within the joint project by Czech Republic and Republic of Srpska meant to increase the capacity of the power-plant "Gacko". The borehole was sampled randomly at places were mollusks were visible. Geological activities were performed mainly by "Geozavod" from Zvornik, not to mention the Czech crow. "Geozavod" enlisted specialists from various areas of paleontology of the Geological Institute, Belgrade, and beyond.

### The column of the drill hole GS-1

The drill hole is 185 m deep (Krstić *et al.* 2007) The uppermost part of the column, up to 38 m, includes marly sediments with varying amounts of sand, occasionally including fossils. The so-called **Youngest coal** (**$^{7a}$Ng**) was penetrated between 38,55-38,70 m, belongs to huminite, and its woody variant was found at 40,00-40,60 m. This lignite coal was underlain by the *Congeria* layer 40,60-57,40 m (**$^{7}$Ng**), containing sub-vertical cracks at 52,60-54,00 m. This layer covers the so-called **Main coal measure** (**$^{6}$Ng**), at 57,40-74,30 m depths with thin intercalations of marl and sandy marl, laminated in places (62,00-62,10 m). This coal often includes wood pieces of differently sizes. The next layer is a 32 m thick sandy-marly sediment ($^5$**Ng**), reaching 106,20 m of depth (with sub-vertical cracks at 79,00-79,90; 90,35-90,55; 91,00-91,35; 94,70-94,90; 97,30-97,50; 98,25-99,00 m) and containing a layer of grey marl at 87,00-93,20 m. From 106,20 to 120,70 m deep there is the so-called **First underlying coal** seam ($^4$**Ng**) with alternating coal and silt. It is laminated at 107,00-109,60, 113,00-115,40, 116,00-117,15 m. The lowermost part of coal is intercalated by 10 or 5 cm of marl having sub-vertical cracks just below the first underlying coal. From 120,70-132,50 m depth there is again an alternation of yellow and grey marl ($^3$**Ng**), also laminated in the upper part (120,70-123,60 m). From a depth of 132,50 m some greyish-green (tuffogenous) fossiliferous silty marl starts. The so-called **Second underlying coal** seam, at 160,70-169,80 m deep, is about 10 m thick ($^2$**Ng**). Besides the layer of silt it also includes a thin tuff bed at a depth of 165.00-165.15 m. Under the second underlying coal seam some laminated grayish-yellow silt starts ($^1$**Ng**) at a depth of 169,80 m and reaches a depth of 182 m. Then a grayish-green (tuffogenous) marl with $CaCO_3$ concretions, comprising sub-layers of green clay, was penetrated for only 3 m, while the drill hole ends at 185 m.

The 7 paleontological samples were taken only from a 65 m stretch, at a drilling depth of 107.0-172.70 m. Gastropods and gyrogonites were quite fragile due to the activity of ulminic acids from the coal. The same agent may have produced the ostracodes' high transparency.

## RESULTS

Samples from the drilling among meiofossils at GS-1 yielded charophytes, gastropodes, ostracodes, seads and fish teeth. Only two samples were processed for palynomorphs and they, as microfossils, are discussed last.

### Composition of paleontological samples

The structural drill hole GS-1 contained various plant and animal fossils. Charophyta are represented by gyrogonites. In one sample carbonized vascular plant seeds were found. A very rich association of palinomorphs included spores and pollen. Animals: mollusks were represented only by gastropods, and associated ostracodes; fish teeth were quite rare.

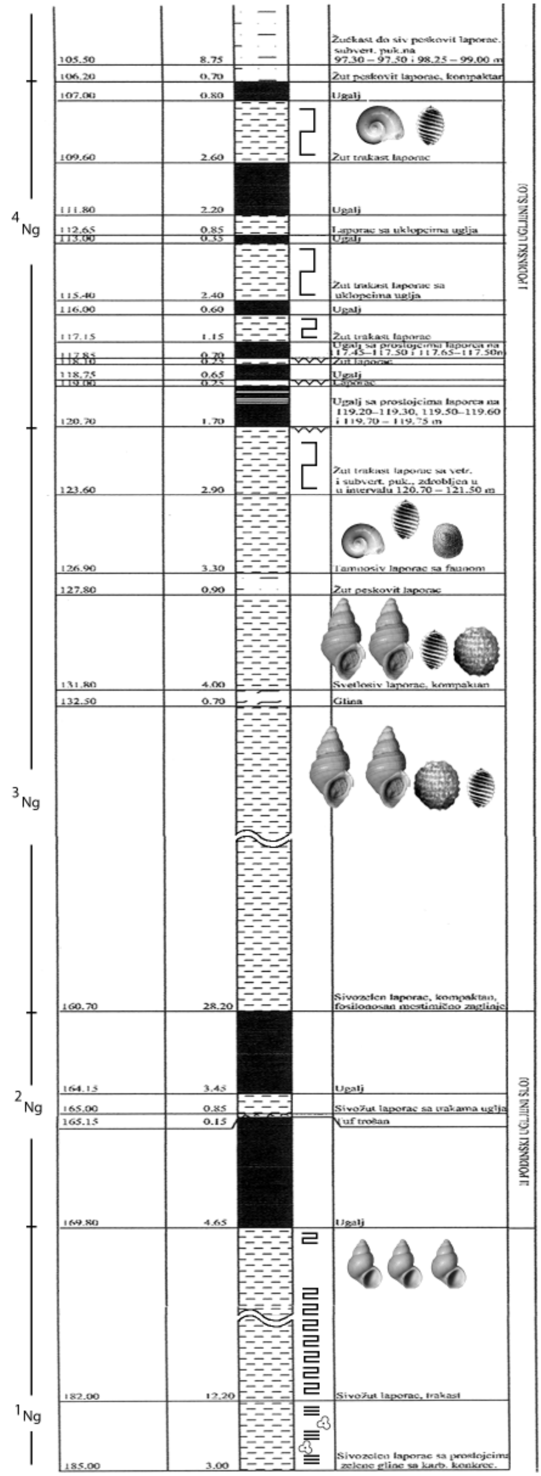



Fig. 1. – Sampled part of the GS-1 drilling column. Legend for textures:
1. laminations,
2. subvertical splittings,
3. bedding,
4. $CaCO_3$ concretions.

107.00-107.40 m **Lacustrine chalk with insignificant amount of sand ($^4$Ng)**
*Planorbis pulići* Brusina 1897 – about 140 damaged shells
*Pseudoamnicola (Staja) šoštarićiana* Brusina – 42
*Segmentina* sp. – 2
de-coiled *Limnidia* apertural parts – 3 fragments
*Succinea* sp. *juv. ex gr. S. drnišiana* – 1 apex
*Chara molassica* Straub – 75 gyrogonites
charophyte *thalli* – several fragments
Fishes *Cypridinae* – 1 pharyngeal tooth
*Candona? aff. paracandidula* malz & moayedpour – 1 RV and 6 juv.
*Candonopsis sp. juv.* – 1 valve
*Cypridopsis sp. juv.* – 1 valve
Relatively rich association of palynomorphs (see bellow)

125.95 m **Lacustrine chalk, silt, mollusk shells excellently preserved ($^3$Ng)**
*Pseudoamnicola (Limnidia) skhiadica* (Bukovski) – 7 shells.
*Pseudoamnicola (Staja) šoštarićiana* Brusina – 2 adults & 1 juv.
*Fossarulus sp. ind.* – 2 fragm.
*Planorbis sp. ind.* – 1 fragm.
de-coiled *Limnidia* apertural parts – single fragment
*Chara molassica notata* (Grambast & Paul) Soulié-Märsche – 880 gyr.
*"Harrisichara" sp.* – 21 gyrogonites
*Chara cf. longovata* Papp. – few specimens
*Candona? aff. paracandidula* juv. – 1 valve of an older larva
*Cypridopsis biplanata* Straub, *sensu* Sokač – a female RV
*Cypria sp. ind. cf. C. sp.* Krstić 1987 – 1 damaged female LV
*Bradleystrandesia aff. besti* (Malz) *juv.* – 4 valves of various age

126.50 m **Clayey-marly silt, gray in color ($^3$Ng)**
*Ancylus cf. illyiricus* Neumayer – 5 apices and many fragments
*Helicidae sp. et gen. indet.* – a protoconch and parts of the whorls
*Succinea sp. ex gr. S. drnišiana* – 1 apex and a part of whorl
*Planorbis pulići* Brusina – 1 whole and 8 damaged shells
*Fossarulus sp. ind.* – 1 fragment
*Cypria sp. cf. C. sp.* Krstić 1987. – 2 fragments of adults & 1 LV juv.
Carbonized plant seeds - 4 specimens

130.85 m **Calcareous silt, light gray ($^3$Ng)**
*Fossarulus tricarinatus* Brusina – 790, mostly apices
*Planorbis pulići* Brusina – 3 shells
*Succinea sp. ex gr. S. drnišiana* – 1 apex and 2 damaged shells
*Lymnaea (Omphiscola) aff. servica* Kovalenko – 1 damaged shell
*Helicidae sp. et gen. indet.* – several fragments, also of the apertural rim
*Chara cf. molassica* Straub – over 300 gyrogonites
*"Harrisichara"* sp. – 139 gyrogonites
*Chara aff. woltzii* (Unger) – 38 gyrogonites
*Sphaerochara* sp. – 27 gyrogonites
*Chara molassica notata* (Grambast & Paul) Soulié-Märsche – 22 gyr.
*Candona? aff. paracandidula* Malz & Moayedpour – LV female, LV and RV male, 54 juv.

142.05 m **Greenish clayey marl (tuffaceous) ($^3$Ng)**

*Fossarulus tricarinatus* Brusina – 155 apices and 24 whole specimens
*Succinea* sp. *ex gr. S. drnišiana* – 5 apices and several fragments
*Lymnaea (Omphiscola) aff. servica* Kovalenko – 2 fragments
*Planorbarius* or *Biomphalaria? sp.* (network lines) – 2 damaged exemplares
*Sphaerochara* sp. – 126 gyrogonits
*“Harrisichara”* sp. – 27 gyrogonites
*Nitellopsis cf. meriani* (Braun) Unger - 7 gyrogonites
*Candona? aff. paracandidula* Malz & Moayedpour – 29 juveniles LV + RV
Fish teeth, one hook-like and other conical – 2 teeth

162.30 m **Coal with 23% of ash and 16% of evaporable matter ($^2$Ng)**

172.70 m **Silt, sandy, with a component of the lacustrine chalk ($^1$Ng)**

*Pseudoamnicola (Limnidia) skhiadica* (Bukovski) – 50 ap. and shells
*Fossarulus tricarinatus* Brusina 1870 – 1 apex + almost smooth fragments
*Succinea sp. ex gr. S. drnišiana* – 1 apex and a larger fragment
*Helicidae sp. et gen. indet.* – several larger fragments
charophyte *talii*, 2 fragments
*Candonopsis cf. arida* Sieber, *sensu* Malz & Moayedpour — 2 LV and 1 RV females, LV and RV juv.
*Candona? aff. paracandidula* Malz & Moayedpour– 1 LV male, 21 juvs of various ages
*Cypris sp. nov.* – fragment of an adult RV and 11 late molts
*Cyclocypris* sp. – LV and RV female
*Pseudocandona sp. juv.* – 4 valves of variously aged molts
*Cypridopsis sp. juv*. - 1 LV
A very rich association of palynomorphs ( see below)

The systematic position of some species is more closely presented in following pages.

## SYSTEMATIC PALEONTOLOGY

### Charophytes

*Sphaerochara sp.* (Pl. II figs 1-4) – In the studied samples it is relatively rare. Its fully rounded shape, small size and the shape of the basal plate visible from the specimens of Maoče site (reported by Krstić *et al* 2008) match the genus *Sphaerochara.*

*Chara molassica molassica* Straub, 1952, (Pl. II, fig. 6) - This was the most common gyrogonite at 107.0, 125.05 and 130.85 m, with up to several hundred specimens within a single sample. The spiral cells of gyrogonites are concave while its two sharp ribs seem merged at the suture. Its shape could be more or less elongated.

*Chara molassica notata* Grambast & Paul, 1965., Soulié-Märsche, 1989., (Pl. II, fig. 10) - It differs from the previous taxon in having a row of small pustules of variable density along the middle of its concave cells. According to Straub (1952) it is larger than the previous form. At Gacko (125.95 m) the ellipsoid *notata* are more common than the pyriform ones. *Chara cf. longovata* Papp, 1951, appears at a depth of 125.95 m in the drill hole GS-1. It was described from Pannonian E, in Vienna Bassin. The height of our specimens varies between 0.5-0.6 and its width is around 0.35 mm.

*"Harrisichara" sp.* (Pl. I figs 16 a-c, II fig. 11) - This is the largest taxon of charophytae algae (stoneworts) at Gacko, abundant at the open pit. The *"Harrisichara" sp.* gyrogonite is barrel-shaped (the typical specimen) or, rarely, ovate (Pl. II, Fig. 11). On the side view it shows 8-9 whorls. The apex is slightly flattened (Pl. I fig. 16c). The base is mostly columnar around the basal pore, but not in the typical secimens where it is flattened and the column around the pore is very short. The basal pore is sometimes situated on a low stalk (in the ovate forms) but most often it sits on a quite small protrusion at the middle of the flattened basis. The ends of the spiral cells around the basal pore are not widened (Pl. I fig. 16b). The basal plate was not studied. The spiral cells are covered with tightly arranged large tubercles, with the rare exceptions in the stunted pyriform specimens (Pl. II fig. 11). It is possible to see thin ridges along the sutures but not the sutures themselves. The size of the photographed specimen: height 1.66 mm, diameter 1.47 mm. The pyriform specimen is poorly calcified and somewhat smaller: height - 1.40 mm.

*Nitellopsis merianii* (Braun) Unger, 1850 (Pl. II figs 12-14) - The specimens from Gacko, GS-1 at a depth of 142 m, are placed into *Nitellopsis merianii.* In the poorly calcified specimens from different sites, such as in Plevlja where the figured (Pl. II fig. 13) specimen comes from, the opening around the basal pore does not have the funnel-form structure while the partecalcines are much thinner and concave. In fully calcified gyrogonits, as in *N. merianii* from Maoče Lower Miocene (shown by Krstić *et al.* 2008) and from Middle Miocene of Tavnik (Pl. I figs 14-15), the shape is very variable. In Tavnik, besides the typical pyriform ones there are also globular forms, where the convex spiral cells are uneven and sutures between them deep (Pl. I fig. 14). There are about 7 whorls in sideview. One pyriform gyrogonite of Tavnik has only 4 spiral cells. *N. merianii* has a wide stratigraphic distribution throughout the Miocene, in Europe and Asia (Soulie-Märsche *et al.* 1997), and intrudes in NW Africa where again both morphs, *N. merianii merianii* and *N. merianii globula*, as presented by Soulie-Märsche *et al.* 2002, appear together.

## Gastropodes

We will comment only on the few gastropoda species: *Fossarulus tricarinatus* Brusina, 1870 - The forms *F. bulići bulići* Brusina, 1897, and *F. bulići complanatus* Brusina, 1897, from the same locality, are synonymous. Nearly smooth *F. eginae eginae* Brusina, 1882, *F. eginae ecarinatus* Brusina, 1882, and probably *F. minilifers* Brusina, 1876 appear also to be synonymous. According to the practices of his time, Brusina separated them into different taxa; however, they may only be different morphotypes of a single species geographically or ecologically separated. The sexual dimorphism is not applicable for the genus *Fossarulus.* Some variants in the drawings in the Brusina's (1897) monograph must be attributed to the artist who altered specimens during the drawing process, combining parts of various specimens (*cf.* Brusina 1894: p. 195, the whole first paragraph).

*Pseudoamnicola (Limnidia) skhiadica* (Bukowski, 1895) is a small gastropod. The specimens from the Greek island Kos were later divided into two subspecies – the nominal, smooth one, and the carinated one *P. (Limnidia) skhiadica conica* Willmann, 1981. The second subspecies cannot be distinguished in the material from Gacko, even though conical subspecies had un-whorled the last whorl and the broken apertural unwhorled fragments were recorded in the samples at depths of 107.00 and 125.95 m. In some of shells from Gacko the aperture is partly un-whorled.

Fragments of a large planispiral snail, similar to genus *Planorbarius*, may also belong to the African taxon *Biomphalaria*. The surface of the shell is covered by crisscrossed striae.

*Ancylus cf. illyiricus* Neumayer, 1880, was found at a depth of 126.5 m. The sample includes five specimens – two larger (Pl. I, fig. 10) and three smaller (Pl. I, fig. 11). They are in an excellent state of preservation, so it is possible to see the faint radial ribs diverging from the smooth protoconch.

Some pelecipods (congerias) are known from the bed covering the main coal seam (at 42-57 m in GS-1). A specimen from another place in the "Gacko" mine was reported by Mandić (in 2007) as *Mytilopsis friči* (Brusina).

## Ostracodes

Ostracodes are rare and have very transparent valves. Living together with charophytes, ostracodes have primarily less $CaCO_3$ in the minuscule lenses inside its chitin network. An acidic environment was corroborated by the presence of *Ericaceae* growing in the peat habitats that lead to the coal deposition.

*Cypria* sp. Krstić, 1987, was found in Plevlja, at the site of Rabitlje, with the valves partially deformed, like in most other cypridacea, and unlike small cytheracea which have a stronger shell.

*Cyclocypris* sp. (Pl. III, figs 7-8) matches *C. ovum* (Jurine) *sensu* Janz, 1997 in shape and size. The species includes several similar recent species (cf. Fuhrmann & Pietrzeniuk 1990, Pietrzeniuk 1991, Krstić 1995, 1996). Its Lower and Middle Miocene relative cannot be placed in this recent taxon.

*Candona? aff. paracandidula* Malz & Moayedpour, 1973 (Pl. III figs 1--3) – Female shells from Gacko are similar in shape to the LV female from Eggerian equivalents of Germany (Malz & Moayedpour1973; Pokorny 1986: 303), but Gacko specimens are lower (more slender). Larger juveniles of both regions are very similar to each other, while younger molts are nearly the same. The length of the figured (damaged) LV female from Gacko should exceed 1 mm while the German specimens are insignificantly smaller (0.88-0.98 mm). The height of our figured specimen is 0.526 mm.

*Candonopsis cf. arida* Sieber, 1905, *sensu* Malz & Moayedpour, 1973 (Pl. III fig. 5-6) - The species *C. arida* Sieber, 1905 was described from Middle Miocene of Steinheim (Lutz 1965: 273 as Sarmatian; Schudack & Janz 1997: 439 as middle part of Middle Miocene). *C. arida* has a regularly rounded inner margin and length of 0.685-0.759 mm for LV (Janz 1997: 26). The measurements of the photographed LV of an adult female from Gacko are l-0.841 and h-0.396 mm – so it is larger and more slender. The length of a photographed LV of a last? molt was 0.676 mm. In the Middle Miocene type locality of *C. arida*, Lutz (1965) mentioned *C. kingsleii* and Janz (1997) corrected the reference to *C. aff. kingsleii* according to its greater size and more slender shape than in recent representatives. The species *kingsleii* has a “square” shaped inner margin. From this feature it matches *Candonopsis arida* of Sokač (1979: Pl. I, figs 8-9 no size is given). From the soft limestone of the vicinity of Sinj, containing (according to Šušnjara, in Sokač 1979) 80-95% of $CaCO_3$ (local name “muljika”). Sokač (1979) also determined the species *Candonopsis kingsleii* Brady & Robertson. The form photographed by Sokač (ibid: Pl. I fig. 7) does not belong to the genus *Candonopsis* at all, but to a species from the genus *Pseudocandona*, as there is a molt, determined by Sokač (Pl. II fig. 2) as *Candona praecox* Straub.

*Cypridopsis* sp. (Pl. III, fig. 10) is, according its shape, close to the ovate *C. biplanata* Straub, 1952, *sensu* Sokač, 1979. Such determination is incorrect as *C. biplanata* belong to semimarine biofacies (OMM by Straub 1952). In our small samples it was represented by only one, slightly damaged valve.

*Bradleystrandesia aff. besti* (Malz 1977) (Pl. III, fig. 9) – Juvenils, determined as *B. aff. besti*, is difficult to attribute to any known species. This genus was found by Straub (1952: 495) in Obere Süßwasser Mollase the part of Miocene column of Ulm area and by Lutz (1965: 300) close to Regensburg in Upper Miocene lower part. Malz (1977: 243-244) placed it in the genus *Kassinia* Mandelstam, 1960, and described the new species *besti* on the basis of 11 specimens. In the Middle Miocene of Steinheim basin, Janz (1997) found *Strandesia pustulosa* and two other molt specimens of this genus, *Strandesia* sp. (ibid: 41) and *Strandesia(?)* sp. juv. (ibid: 41-42), one of which may be conspecific with the one from Gacko. It is questionable how many species there are in Miocene, as only juveniles are known. This is the first time that this genus has been collected from the Lower Miocene of the Balkan Peninsula. The genus was attributed to the fauna of the northern hemisphere (Meisch 2000). Recently it was proved that the genus has a global range while 5 species were mentioned as pleuston (on drifted islands) in Brazil (Higuti *et al.* 2007).

## Palynomorphs

Pollen and spores were analyzed from two samples taken at a dept of 107,40 m and immediately below the Second underlying coal seam, at a depth of 172.70 m (see Appendix). The studied plant association was very rich and diverse. It inhabited the shores of Neogene Lake as well as nearby areas. Humid subtropical elements were represented by genera *Taxodium, Glyptostrobus, Nyssa, Cyrillaceae, Cyperus, Arecaceae* and certain species of *Ericaceae* and *Polypodiaceae*. Warm-temperate elements include abundant *Alnus, Pterocarya* and *Rus,* while *Engelhardtia, Carya, Corylus, Ulmus, Carpinus, Tilia, Acer* and *Castanea* were less represented. Xerophilous elements were dominated by species from family *Sapotaceae*, with a smaller percentage of *Leguminosae, Castanopsis* and sclerophyllous types of *Quercus*. The species inhabiting colder areas and higher altitudes were represented by *Picea, Fagus* and a few kinds of *Pinus*.

# DISCUSSION

## Paleoecology

A shallow freshwater lake characterize the layers below the main coal measure, i.e. in the studied part of GS-1 borehole. The most important indicators, besides lacustrine chalk, were charophyta, while ostracodes are good indicators of paleosalinty.

The snow-like flakes of calcium carbonate fell mostly from *Potamogeton* leaves, in the daily photosynthesis cycle that transformed soluble bicarbonate into insoluble calcium carbonate (Jakovljević 1951). So was lacustine chalk formed, so important in sediment place determination.

Charophytes inhabit different depths but they grows underneath and in between the stems of floating plants avoiding places with water nuts. Gyrogonites are only in the shallow water above 7 m, exceptionally to 10 m water depth (Soulié-Märsche *et al.* 2002). The presence of the genus *Chara* may indicate a shallow water table, while the genus *Nitellopsis* may live in deeper lakes (Schudack & Janz 1997).

The ostracodes bellow the main coal seam of Gacko, similarly to those published from the sediments of Sinj (Sokač 1979), do not include typical halophilic or even halotolerant forms. However, the main coal overburden at Plevlja, the Rabitlje-site, includes the inhabitants of saline lakes such as *Sinometacypris, Clonocythere* and others (How *et al.* 2002).

Analysis of pollen and spore association from both samples are interpreted in terms of paleoecology by comparison with extant relatives. The edge of the marsh was characterized by periodic flooding and was overgrown by a typical swamp forest, with a dominance of *Taxodium*, *Glyptostrobus*, *Nyssa*, *Arecaceae*, *Cyrillaceae*, *Cyperus* and *Polypodiaceae*. Representatives of *Ericaceae* are probably characteristic of acidic, peat habitats. Behind the swamp forest, in the areas where the water level was more stable throughout the year, there were some riparian forests dominated by species from the genera *Alnus*, *Carya*, *Pterocarya* and *Engelhardtia*. In the area further away from the swamp, behind the zone of the riparian forest where humidity levels were quite low, there were some zonal polydominant forests presented mostly by deciduous termophilous species from the genera *Corylus*, *Ulmus*, *Carpinus*, *Castanopsis*, *Castanea*, *Rhus*, *Tilia*, *Acer,* some representatives of family *Cornaceae*, and the more xerophilous elements of *Sapotaceae* and *Leguminosae*. Even further from the depositional environment, in the areas of higher altitude, there were some associations of *Fagus* and *Picea*. The different *Pinus* species could inhabit various habitats within the studied area, so their position could not be precisely determined.

## Biostratigraphy

The Tertiary layers of Ulm (southern Germany) were studied by Straub (1952) and range from youngest Oligocene to Lower Miocene. Other authors studied ostracodes of the Lower Miocene of Bavaria, e.g. Sieber (1905), Lutz (1965), Malz & Moayedpour (1973), Malz (1977), Janz

(1997). Schudack & Janz (1997) studied charophyta there. The Lower Miocene ostracodes, defined by mammals, was recognised in the northernmost Czech Republic (Pokorny 1986, Witt 2001). In the Balkan region, Kochansky-Devide and Slišković (1978) studied Miocene *Congeria* and determined its age as “most probably Ottnangian”.

Certain localities in the Dinarides, such as Otilovići near Plevlja and 30 km further toward the SE at the site Maoče (Krstić *et al.* 2008), are of Lower Miocene age according to charophyta biostratigraphy. The site Plevlja-Otilovići includes rare gyrogonites with spiral cells ornamented with regularly spaced transversal riblets, attributed to the species *Rhabdochara langeri*. Soulié-Märsche had determined *Rhabdochara cf. langeri* at the site Maoče (ibid). Therefore the age of the mentioned site is the upper part of Lower Miocene. The genus *Harrisichara* existed during Eocene and Lower Oligocene, but, it seems that a younger relative of *Harrisichara* is present in GS-1 (here as “*Harrisichara”*).

Isotopic detection was intended with the sample (5 kg) from a tuff layer at the transition from $^{8}$Ng into $^{9}$Ng. The firm result was not obtain (de Leeuw *et al.* 2008) according to posibile contamination by overlaing Quaternary cover.

Palynomorph association from Gacko has many similarities to palynomorphs from the Early Miocene locality Kakanj in Bosnia (Pantić *et al.* 1966: 192-193).

## CONCLUSION

The part of the drill-hole GS-1 column studied from a paleontological standpoint included the so-called First and Second underlying coal measure at Gacko (Fig. 1). Lamination and thin layers were occasionally present around the First underlying coal seam, perhaps indicating transport of sand in sublittoral. The subvertical splittings under the lower bed of the First underlying coal seam may indicate desiccation cracks or plant roots. The fossil-bearing marl between the two underlying coal seams corroborates that bioturbation occurred on the bottom of a stable lacustrine environment. Below the so-called Second underlying coal measure there is again lamination, alternating with the fossil-bearing (bioturbated) layers, indicating well oxygenated lacustrine water. The intercalations of green tephra clay, in the last 3 meters of the drilling, show distant volcanic activity.

Variations of biotope, especially the lake depth, may be estimated by comparing various samples. The greenish-yellow silt from 172 m deep includes few small crumbs of lacustrine chalk. The most common gastropod is *Pseudoamnicola skhiadica* while ostracodes are very diverse and characean gyrogonites are absent altogether. The presence of *Succinea* and terrestrial helicids together indicates the vicinity of the shore. The sample from 172.7 m of depth contained a very rich and diverse plant association (see Appendix). It used to inhabit the edges of the deposition basin, as well as the spaces in the inside of the mainland.

Representatives of subtropical swamp vegetation were *Taxodium*, *Glyptostrobus*, *Nyssa*, *Cyrillaceae*, *Cyperus*, *Arecaceae*, as well as some types of *Ericaceae* and *Polypodiaceae*. The broad-leaved deciduous elements included a larger number of *Rhus* and riparian forests elements such as *Alnu* and, *Pterocarya*, while pollen of *Engelhardtia*, *Carya*, *Corylus*, *Ulmus*, *Carpinus*, *Tilia*, *Acer* and *Castanea* were recorded in smaller numbers. The xerophilous elements are dominated by species of *Sapotaceae*, while they also included smaller numbers of *Leguminosae*, *Castanopsis* and scleromorphous *Quercus*. At the highest altitudes *Picea*, *Fagus* and certain species of genus *Pinus* grow.

Silt at 142 m depth is greenish due to a small tephra influence. Also, it seems to be the source of fossils re-deposited in the following sample. The shells of *Fossatrulus tricarinatus* were mainly well-preserved, including the morphotypes of both – lesser (fine-carrinate specimens) and higher water energy (robust-carinate ones). *Charophytae* gyrogonites do not appear in great number. The presence of *Succinea* and *Planorbarius* (or *Biomphalaria*?) would indicate very shallow water, along a close-lying shore.

Grey marly silt at 130 m depth did not show re-sedimentation structures, but the large number of apices of *Fossatrulus tricarinatus* still indicates reworking from an older layer. There were abundant gyrogonites. They might originate in the sparsely grown meadow from the vicinity, although reworking is also probable. Ostracodes and *Succinea* are very rare. The depth is ca 2 meters.

At a depth of 126.5 m the environment changed abruptly. The land snails (*Helicidae*, *Succinea*) and plant seeds both brought from shore prevailed. There were no charophytes, possibly indicating turbid water. The preservation of *Planorbis pulići* would be re-sedimentated. The only autochthonous organism was the thin-shelled small *Ancilus illyricus*. This layer corresponds to a shallow but high energy lottic environment.

Lacustrine chalk at 125.95 m depth was deposited in a somewhat deeper and calm water, where the aquatic plants (*Potamogeton*, *Nymphaceae*, but not *Trapa* while have to characeans opposite requirements of nitrogen and phosphorus) were regularly producing flakes of $CaCO_3$ during photosynthesis. The growth of charophyta was much denser, building meadows. Gastropods and ostracodes are rare. Water depth could be estimated as more than 7 m.

Chalk with a sparse presence of sand appears at a depth of 107 m, supporting the transport of sand from littoral for lamination forming. Small gastropods were floated with sand grains as charophyta gyrogonits. Ostracodes are rare. The water depth is less than 6 m. The sample from 107.4 m of depth included a relatively poor plant association that could not be used to determine a more detailed reconstruction of vegetation, especially as most of the palinomorphs were determined only to the family level (see the Appendix). In contrast to the sample from 170.7 m, this sample includes representatives of *Asteraceae*, which may indicate a wider distribution pattern of steppe or other lowland areas. This sample also includes higher amounts of large fragments of plant matter (remains of woody tissue of various shapes, sizes and structures), indicating the potentially greater energy of the relief at the time when this sediment was deposited – the strong torrential watercourses transported the large plant fragments to the deposition basin together with the terrigenous.

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Thanks to the paleontological analysis of drill hole GS-1 we could, for the first time, clearly distinguish the occurrence of a shallow feshwater level below the main coal seam in Gacko, and in the whole Dinaric lake--system. Above the main coal there is a level with congeras (deposited in slightly saline hard water) of a relatively deep lake. Its depth was greater than 10 m, evident from the absence of gyrogonites there.

The lake gradually became shallower with the appearance of an increasing number of islands (cf. Katzer 1921: 30, fig. 8; Krstić *et al.* 2003). The biofacies of the later phase of a mineralized lake were more uniform (cf. Kochansky-Devide & Slišković 1978) while the lake surface area seasonally varied (cf. Karaman & Beeton 1981).

After the deposition of Miocene sediments in the pre-formed dilatational depression, the front leading edge of the Kuč zone moved in a southwestern direction, pushing the Neogene of Gacko Plain into a shallow syncline (Mirković *et al.* 1980). The detailed study of paleostress in the Central Dinarides "indicates a NE-SW contraction as well as a subordinate NW-SE extension related to early Miocene shortening of Dinaric orogenic wedge" (Ilić & Neubauer 2005).

## Appendix

## Palinomorph assemblages from GS-1, 107,40 m

*Pityosporites microalatus* Th. Pf. 1953 (*Pinus haploxylon*)
*Pityosporites* sp.
*Tricolporopollenites cingulum pussillus* Th. et Pf. 1953 (*Castanopsis*)
*T. cingulum oviformis* Th. et Pf. 1953 (*Castanea*)
*T.* aff. *megaexactus* (R. Pot. 1931c) R. Pot. 1960 (*Cyrillaceae*)
*Tricolpropollenites microreticulatus* Pf. Th. 1953
*T. macroechinatus* Trevisan 1967 (*Compositae*, *Tubuliflore*-type)
*Araliaceoipollenites edmundi* R. Pot 1960 (*Araliaceae-Cornaceae*)
*Tricolpopollenites microhenrici* Th. et Pf. 1953 (*Cupulifere*)
*Tetracolporopollenites obscurus* Pf. Th. 1953 (*Sapotaceae*)
*T. sapotoides* R. Pot. 1960
*T. biconus* Pf. Th. 1953 (*Sapotaceae*)
*Umbeliferae*
cf. *Cercidifilum* sp.
*Sparganiaceaepollenites sparganioides* (Mayer 1956) Krutzsch 1970 (*Typha*)
*Oleaceae*-type

## Palynomorph assemblages from GS-1 172.70 m

*Stereosporites* sp.
*Laevigatosporites haardti* Pf. Th. 1953 (*Polypodiaceae*)
*Verrucatosporites microverrucatus* Krutzsch 1967
*Ischyosporites asolidus* Krutzsch 1967
*Monocolpopollenites* sp. (*Arecipites* sp.)
*Inaperturopollenites dubius* Pf. Th. 1953 (*Taxodiaceae-Cupresaceae*)
*Inaperturopollenites hiatus* Krutzsch 1950 (*Taxodium* sp.)
*I. radiatus* Krutysch 1971
*Pityosporites microalatus* Th. Pf. 1953 (*Pinus haploxylon*)
*P. alatus* Th. Pf. 1953 (*Picea* sp.)
*Platycaryapollenites miocaenicus* Nagy 1969 (*Engelhardtia* sp.)
*Subtriporopollenites simplex* Raatz 1937 ex Potoniė 1960 (*Carya* sp.)
*Triporopollenites coryloides* Pflug 1953 (*Corylus* sp.)
*Ulmipollenites undulosus* Wolff 1934 (*Ulmus* sp.)
*Carpinipites carpinoides* (Pf. 1953) Nagy 1985 (*Carpinus* sp.)
*Alnipollenites verus* R. Pot 1934 (*Alnus* sp.)
*Polyatriopollenites stellatus* Raatz 1937 (*Pterocarya* sp.)
*Intratriporopollenites instructus* Th. Pf. 1953 (*Tilia* sp.)
*Nyssapollenites kruschi* Nagy 1969 (*Nyssa* sp.)
*Faguspollenites minor* Nagy 1969 (*Fagus* sp.)
*Tricolporopollenites cingulum pussillus* Th. et Pf. 1953 (*Castanopsis* sp.)
*T. cingulum oviformis* Th. et Pf. 1953 (*Castanea* sp.)
*T.* aff. *megaexactus* (R. Pot. 1931c) R. Pot. 1960 (*Cyrillaceae* sp.)

*Rhiopites pseudocingulum* (R. Potonié 1931) R. Potonié 1960 (*Rhus* sp.)
*Araliaceoipollenites edmundi* (R. Potonié 1931*)* R. Potonié 1960 (*Araliaceae-*
*-Cornaceae*)
*Tricolpopollenites henrici* Krutzsch 1961. (cf. *Quercus*)
*T. asper* Pf. Th. 1953 (*Quercus* sp.)
*T. microhenrici* Th. et Pf. 1953 (*Cupuliferae*)
*T. liblarensis* Th. Pf. 1953 ssp. *liblarensis* (*Cupuliferae-Leguminosae*)
*Aceripollenites sp.*
*Cyperaceapollis* sp.
*Tetracolporopollenites obscurus* Pf. Th. 1953 (*Sapotaceae*)
*T. sapotoides* R. Pot. 1960
*T. microrhombus* Pf. Th. 1953 (*Sapotaceae*)
*T. biconus* Pf. Th. 1953 (*Sapotaceae*)
*Umbeliferoipollenites* sp.
*Ericipites ericius* (R. Pot. 1931b) R. Potonié 1960 (*Ericaceae*)
*?Goniaulax* cf. *reticulatus* Nagy 1969
?*Histrichosphaeridae* gen. et sp. indet.

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## ФОСИЛИ ИЗ БУШОТИНЕ GS-1 КОД ГАЦКОГ, РЕПУБЛИКА СРПСКА

НАДЕЖДА КРСТИЋ, ЈОВАН ОЛУЈИЋ, СЛАВИЦА ЋАЈИЋ,
ДЕСА ЂОРЂЕВИЋ-МИЛУТИНОВИЋ, ЉИЉАНА ТАНАСКОВИЋ

### Р Е З И М Е

Део стуба бушотине, који је палеонтолошки проучен, обухвата Први и Други подински слој угља у Гацку (сл. 1). Око Првог подинског угља често се јавља ламинација и танки слојеви, што би указивало на дејство таласа. Субвертикалне пукотине испод угљених слојева указивале би на исушивање, евентуално на трагове корења. Фосилоносни лапори између два Подинска угљена слоја последица су биотурбације и означавају стабилан језерски режим; њихова зеленкаста боја потицала би од тефта примеса, можда услед преталожавања. Испод другог подинског угља поново се јавља ламинација у смени са фосилоносним слојевима што указује на добро аерисану воду језера. Прослојци зелене туфогене глине, са последња 3 метра бушотине, формирани су под дејством удаљене вулканске активности.

На основу садржаја појединих проба може се пратити варирање биотопа, посебно дубине језера. Због тога ћемо окренути опис бушотине - одоздо на горе.

Зеленкасто-жућкаст алеврит са 172 m садржи и грумуљице језерске креде. Најбројнији је пуж *Pseudoamnicola skhiadica* док су остракоди разноврсни захваљујући отсуству хара. *Succinea* и терестричи хелициди указују на близину обале. Предстасвници субтропске мочварне вегетације насељавали су обалне делове (*Taxodium, Glyptostrobus, Nyssa, Cyrillaceae, Cyperus, Arecaceae*, као и неке врсте *Ericaceae* и *Polypodiaceae*). Од арктотерцијарне флоре у већем проценту заступљени су елементи галеријских шума *Alnus, Pterocarya* и *Rus*, док су *Engelhardtia, Carya, Corylus, Ulmus, Carpinus, Tilia, Acer* и *Castanea* нађени у мањем броју. Од ксерофилних елемената доминирају врсте фамилије *Sapotaceae*, а у мањој мери и *Leguminosae*, *Castanopsis* и склероморфни *Quercus.* На већим висинама расли су *Picea*, *Fagus* и неке врсте рода *Pinus*.

Алеврит са 142 m, зеленкаст услед примеса туфа изгледа да је извор фосила претоложених у следећој проби. Љуштурице *Fossatrulus tricarinatus* сачуване су често целе тако да се разликују морфотипови мање (примерци нежних ребара) и веће енергије средине (са снажним ребрима). Гирогонита има мање. Присуство *Succinea* и *Planorbarius* указивало би на веома плитку воду, у близини обале.

Сиви лапоровити алеврит на 130 m не садржи видљиве структуре преталожавања, али огроман број врхова *Fossatrulus tricarinatus* указује да су испрани из старијег слоја, какав је онај на 142 m. Гирогонити ситних и крупних хара су бројни, а можда потичу од проређене подводне ливаде у близини, мада је порекло из старијег слоја вероватније. Остракоди и *Succinea*, која насељава део трске изнад воде веома су ретки. Дубина око 2 m.

Средина се, на 126,5 m, нагло мења. Преовлађују копнени пужеви (*Helicidae, Succinea*) и семење нането са обале. Хара нема јер избегавају мутну воду. Очуваност *Planorbis pulici* указује на преталожавање. Једини аутохтони организам је ситан *Ancylus illyricus* танке љуштурице. Средина је лотична.

Узорак са 125,9 m таложен је у мало дубљој и мирној води, у којој водене цветнице, током фотосинтезе, и даље производе пахуље $CaCO_3$. Харофитне алге расту много гушће и скоро да граде праве подводне ливаде. Пужеви су ретки као и остракоди. Дубина воде је већа од 7 m.

Језерска креда са мало песка, која се јавља на 107 m, потврђује теренску претпоставку о дејству таласа на настанак ламинације. Ситни пужеви су флотирани заједно са зрнима песка а харе су, као аутохтоне, расле између виших биљака са чијег су лишћа вејале пахуље $CaCO_3$. Због тога што су харе преузимале калцијум остракоди су ретки. Дубина воде је била мања од 6 m.

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Захваљујући палеонтолошкој анализи бушотине GS-1 први пут се сада јасно разликује плитководно-слатководни ниво испод главног угљеног нивоа у Гацком, али и у целокупном Динаридском систему језера. Изнад главног угљеног пакета налази се ниво (таложен у сланој и тврдој води) у доста дубоком језеру, знатно дубљем од 10 m, где више нема гирогониота хара.

Динаридско Језеро је било велико као (северна) половина данашњег Каспија. Касније Језеро оплићава, али постепено и уз појаву све већег и већег броја острва. Биофације минерализованог језера касне фазе су уједначене (упореди Kochansky-Devide & Slišković 1978) а површина језера варира. Било је веће зими и у пролеће, кад се вода овог карстног језера издизала а делови језера спајали расејавајући при том исте врсте конгерија у своје удаљене делове. Током суве сезоне језеро се повлачило и смањивало. Исто то се сада догађа са Скадарским Језером и његовим годишњим флуктуацијама до 6 m (Karaman & Beeton 1981).

После таложења миоценских седимената, у раније формираној дилатационој депресији, чело навлаке Кучке зоне је, при свом кретању према југозападу, убрало неоген Гарачког Поља у плитку синклиналу (Mirković *et al.* 1980). Детаљна студија палеостреса у Централним Динаридима "*указује на СИ-ЈЗ сабијање и, у мањој мери, СЗ-ЈИ развлачење повезано са доњемиоценским скраћивањем Динаридског клина*" (Ilić & Neubauer 2005).

## PLATE 1.

1-2. *Fossarulus tricarinatus* BRUSINA, 1870, GS-1 from 142.05 m (1) with strongly defined and (2) with weak longitudinal ribs, height about 8 mm.

3. *Lymnaea (Omphiscola) aff. servica* KOVALENKO, 2004, GS-1 from 142.05 m, height 2.67 mm.

4. *Succinea sp. ex gr. S. drnišiana juv*., GS-1 from 107.4 m, height 2.55 mm.

5. *Pseudoamnicola (Staja) šoštarićiana* BRUSINA 1974, GS-1 from 107.4 m, height 0.96 mm.

6. *Segmentina sp.*, GS-1 from 107.4 m, width (under the $45^o$ angle) 1.11 mm.

7-8. *Planorbis pulići* BRUSINA, 1897, GS-1 from 107.4 m, widths 3.0 and 3.5 mm.

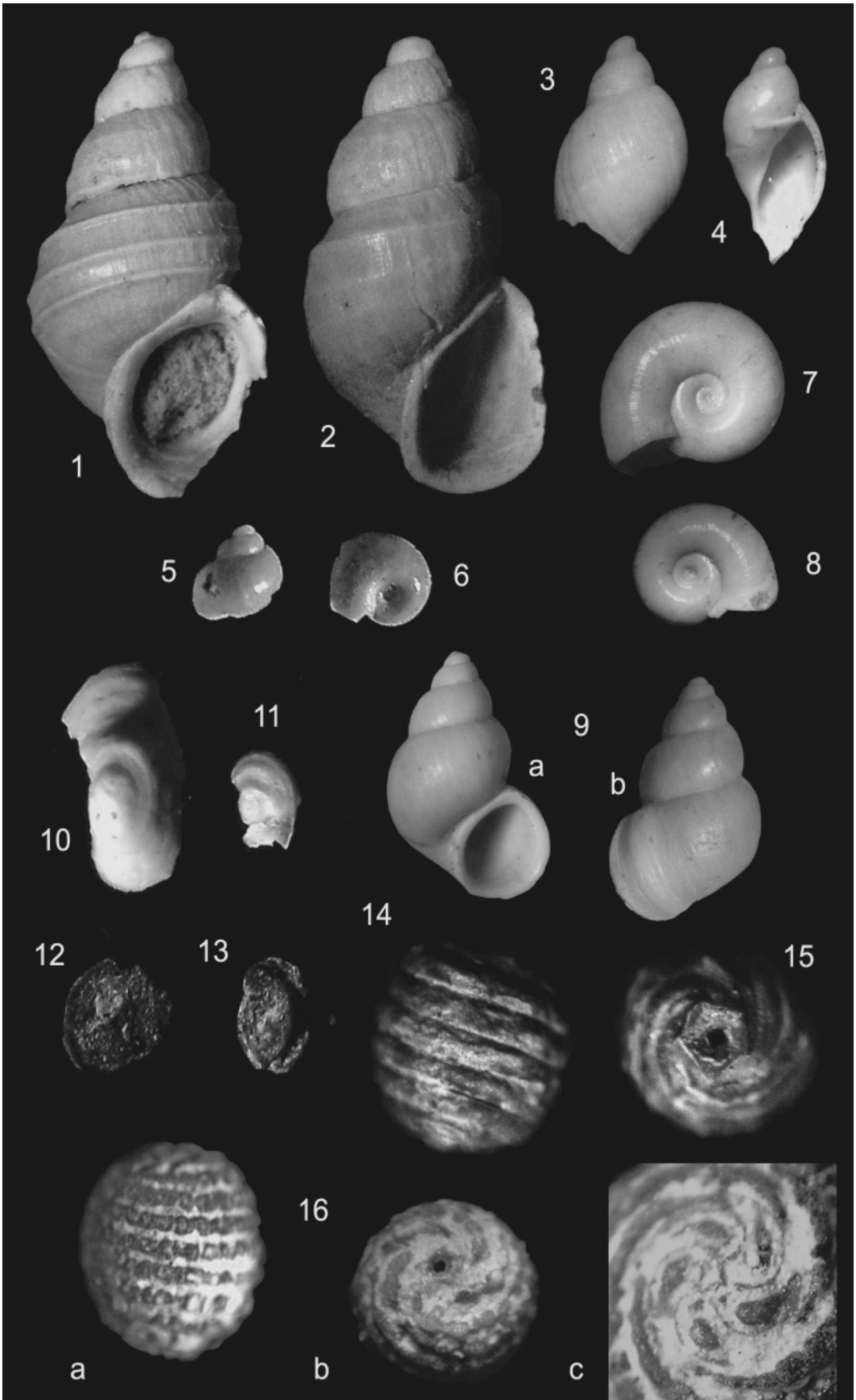
9. (a-b) *Pseudoamnicola (Limnidia) skhiadica* (BUKOVSKI, 1895), GS-1 from 125.95 m, height 3 mm.

10-11. *Ancilus cf. illyricus* NEUMAYR, 1880, GS-1 from 126.5 m, length (11) 2.16 and (12) 0.96 mm.

12-13. *Seeds*, GS-1 from 126.5 m length (13) 1.15 and (14) 1.08 mm.

14-15. *Nitellopsis merianii globula* (MÄDLER) SOULIE-MÄRSCHE *ET AL.*, 2002, Upper Miocene, Tavnik near Kraljevo, size ca.: height 1.156, diameter 1.08 mm.

16. (a-c) "*Harrisichara*" *sp.*, GS-1 from 130.85 m, height 1.66, diameter 1.47 mm.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## PLATE 2.

1. Group "*Gyrogona medicaginula* (LAMACK, 1804)" *sensu* NÖTZOLD, 1975.

1-4. *Sphaerochara sp.*, GS-1 from 142.05 m, height 0.34-042 mm.

5. *Chara aff. woltzii* (UNGER, 1850), GS-1 from 130.85 m, height 0.55 mm.

6. *Chara cf. molassica* STRAUB, 1952, GS-1 from 130.85 m, height 0.59 mm.

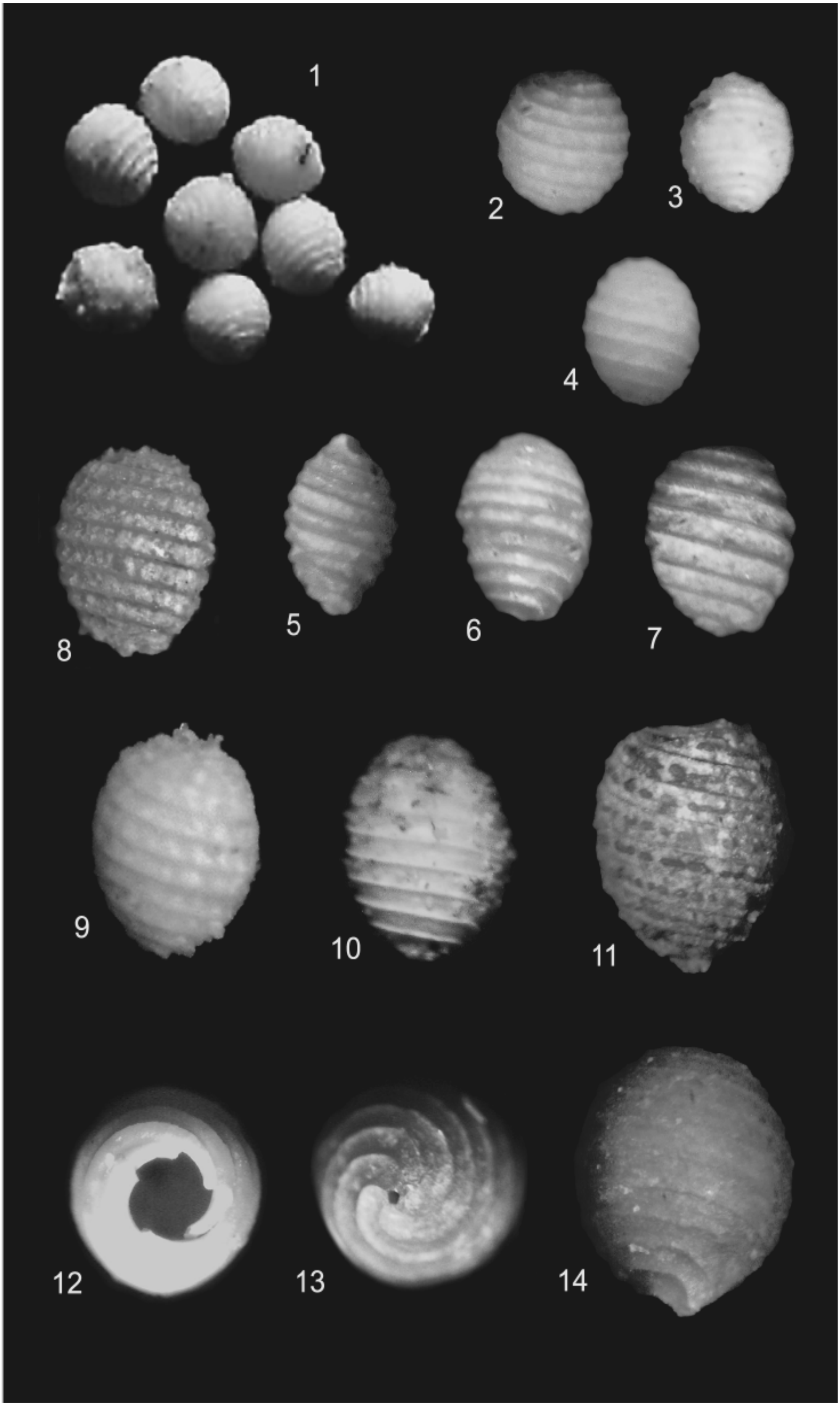
7. *"Lychnothamnus (Rhabdochara)" sp.*, GS-1 from 130.85 m, height 0.78 mm.

8-9. *Lychnothamnus (Rhabdochara) praelangeri* CASTEL 1967, with transversal ribs on spiral cells, Plevlja, Otilovići, point 301, height about 0.95 mm.

10. *Chara molassica notata* GRAMBAST & PAUL 1965 *sensu* SOULIÉ-MÄRSCHE, 1989, GS-1 from 130.85 m, height 0.65 mm.

11. "*Harrisichara" sp.*, stunted variety, GS-1 from 130.85 m, height 1.40 mm.

12-14. *Nitelopsis merianii* (BRAUN) GRAMBAST & SOULIÉ-MÄRSCHE 1972, Plevlja, Otilovići, point 301, height of the gyrogonite 1.40 mm.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## PLATE 3.

1. *Candona? aff. paracandidula* MALZ & MOAYEDPOUR, 1973, female LV (a) and detail (b) GS-1 from 130.85 m.

2-3. *Candona? aff. paracandidula* MALZ & MOAYEDPOUR, 1973, RV juv. of 5th and LV of 4th moltings, GS-1 from 125.95 m.

4. *Pseudocandona sp*., RV juv., GS-1 from 172.7 m.

5-6. *Candonopsis cf. arida* SIEBER, 1905, *sensu* MALZ & MOAYE-DPOUR, 1973 juvenile (5) and adult (6), GS-1 from 172.7 m.

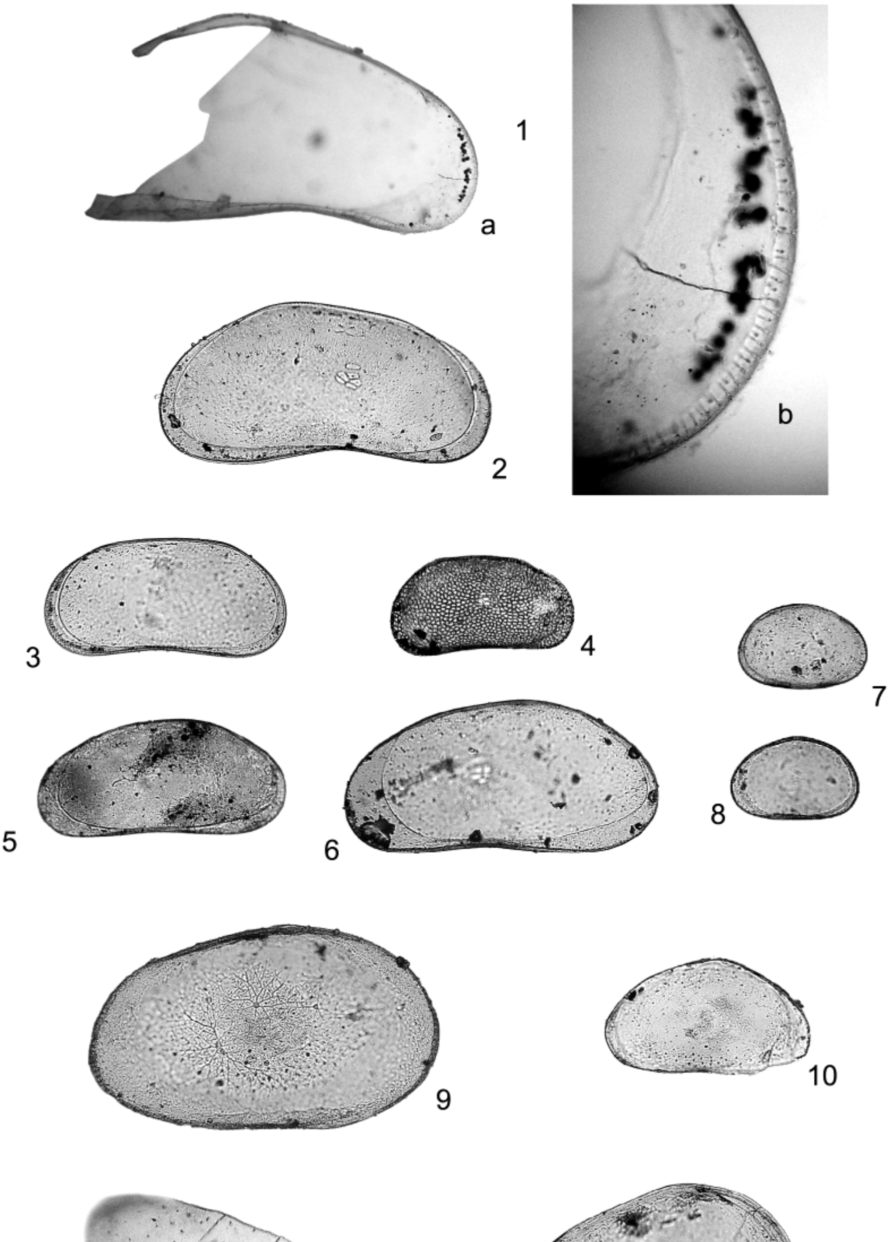
7-8. *Cyclocypris sp*., GS-1 from 172.7 m.

9. *Bradleystrandesia aff. besti* (MALZ, 1977) *juv*., GS-1 from 125.95 m.

10. *Cypridopsis cf. biplanata* Straub, 1952, GS-1 from 125.95 m.

11-12. *Cypris sp. nov*., a part of LV adult (11) and RV juvenile, GS-1 from 172.7 m.

All the ostracode valves have the same magnification– see the scale.



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